

UNCLASSIFIED

AP 284 787

*Reproduced
by the*

**ARMED SERVICES TECHNICAL INFORMATION AGENCY
ARLINGTON HALL STATION
ARLINGTON 12, VIRGINIA**



UNCLASSIFIED

This Document Contains
Missing Page/s That Are
Unavailable In The
Original Document

**Best
Available
Copy**

NOTICE: When government or other drawings, specifications or other data are used for any purpose other than in connection with a definitely related government procurement operation, the U. S. Government thereby incurs no responsibility, nor any obligation whatsoever; and the fact that the Government may have formulated, furnished, or in any way supplied the said drawings, specifications, or other data is not to be regarded by implication or otherwise as in any manner licensing the holder or any other person or corporation, or conveying any rights or permission to manufacture, use or sell any patented invention that may in any way be related thereto.

63-1-1

284787

CATALOGUED BY ASTIA
AS AD NO.

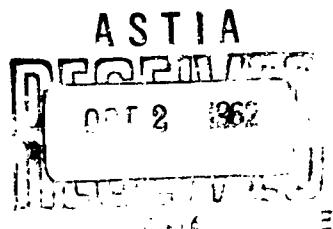
284787

AIRPORT MARKING AND LIGHTING SYSTEMS:
A SURVEY OF OPERATIONAL TESTS
AND HUMAN FACTORS, 1959-1961

W.S. Vaughan, Jr.
Terrence S. Luce
R.G. Kassebaum

HSR - RR - 61/13 - Mk - X

May 1962



Prepared Under:

Contract No. FAA/BRD-401

Systems Research and Development Service
Federal Aviation Agency
National Aviation Facilities Experimental Center
Atlantic City, New Jersey

HSR

human sciences research inc

FILLMORE AND WILSON BOULEVARD
ARLINGTON 1, VIRGINIA

**AIRPORT MARKING AND LIGHTING SYSTEMS:
A SURVEY OF OPERATIONAL TESTS
AND HUMAN FACTORS, 1959-1961**

**W.S. Vaughan, Jr.
Terrence S. Luce
R.G. Kassebaum**

HSR-RR-61/13-Mk-X

May 1962

**"This report has been prepared by Human Sciences Research, Inc.
for the Systems Research and Development Service (formerly Bureau
of Research and Development), Federal Aviation Agency, under
Contract No. FAA/BRD-401. The contents of this report reflect
the views of the contractor, who is responsible for the facts and the
accuracy of the data presented herein, and do not necessarily reflect
the official views or policy of the FAA."**

FOREWORD

The purpose of this report is to bring up to date a compilation of information about airport marking and lighting systems contained in "Airport Marking and Lighting Systems, A Summary of Operational Tests and Human Factors," HSR-RR-59/1-MK, May 1959. The previous report contained a summary of information developed during 1949-1958. This present supplementary report includes material generated during 1959-1961.

The authors acknowledge the help of the following men, long experienced in the problems of airport marking and lighting, who directed the authors to recent and important developments in their areas of interest:

Mr. George K. Clement - Electrical Engineer, USAF

Mr. Russell D. Hartz - Head, Shore Based and Seadrome Section, Bureau of Ships, USN

Mr. Robert F. Gates - Air Traffic Control Specialist, National Aviation Facilities Experimental Center

Mr. Leslie C. Vipond - Supervisor Engineer, Federal Aviation Agency

Mr. Charles A. Douglas - Photometry and Colorimetry Section, National Bureau of Standards

Mr. Walter C. Fisher - Lighting Engineer, Federal Aviation Agency

Lt. Col. Richard S. Griffith - Air Traffic Control Specialist (General), National Aviation Facilities Experimental Center

Mr. Cecil B. Phillips - Supervisory Electrical Engineer (Illumination), National Aviation Facilities Experimental Center

Dr. Robert K. McKelvey, Research Division, National Aviation Facilities Experimental Center, monitored the project effort and assisted the authors in administrative as well as content areas.

Dr. R. K. McKelvey and Mr. C. A. Douglas reviewed earlier drafts of this report and their suggestions improved the final product.

Luna Wallace prepared the illustrations; Rose Anna Betts, Nancy Iannuzzi, and Bette Listman typed the report.

Human Sciences Research, Inc., Arlington 1, Virginia
AIRPORT MARKING AND LIGHTING SYSTEMS:
A SURVEY OF OPERATIONAL TESTS
AND HUMAN FACTORS, 1959-1961,
May, 1962, 237 pp., includ. 13 illus.
(Contract FAA/BRD-401)

ABSTRACT

In May of 1958, Human Sciences Research, Inc. (HSR) published a report summarizing operational test results and human factors knowledge relevant to the design of airport marking and lighting systems. This report, "Airport Marking and Lighting Systems, A Summary of Operational Tests and Human Factors," HSR-RR-59/1-Mk, May 1959, summarized operational test results from the 1946 Arcata work on approach lighting to the 1958 tests of narrow gauge runway lighting at Dow Air Force Base.

This present report is a supplement to the first and contains operational test results and human factors information generated during 1959-1961. Operational tests of airport marking and lighting since 1959 have been concentrated in three areas: beacon systems, approach and runway combined systems, and angle of approach indicators. Test results in these areas are summarized in Part I; the individual reports are annotated in Part II.

Human factors work during 1959-1961 is presented in five categories: pattern recognition, luminance and visual acuity, dynamic visual acuity and motion perception, size-distance judgments, and response latency to visual stimuli. Important recent results in these areas are highlighted in Part I and report annotations are presented in Part II.

An author index of all annotations is contained in Part II of the report. In those reports which have only the name of the organization, with no specific authors listed, the name of the organization will appear in alphabetical order in the author index. Following each reference are page numbers which indicate where the reference is discussed, Part I; and annotated, Part II.

TABLE OF CONTENTS

<u>Title</u>	<u>Page</u>
FOREWORD	i
ABSTRACT	iii
PART I: SUMMARY OF OPERATIONAL TESTS AND HUMAN FACTORS RESEARCH, 1959-1961	
Operational Tests and Design Developments	I-1
Beacons	I-2
Angle of Approach Indicators	I-5
Approach and Runway Lighting Patterns	I-20
Components and Materials	I-37
Methodological Problems and Developments	I-39
Human Factors Research	I-47
Pattern Recognition	I-48
Luminance and Visual Acuity	I-49
Dynamic Visual Acuity and Motion Perception	I-51
Size-Distance Judgments	I-53
Response Latency to Visual Stimuli	I-54
PART II: ANNOTATED BIBLIOGRAPHY OF OPERATIONAL TESTS AND HUMAN FACTORS RESEARCH, 1959-1961	
Operational Tests and Design Developments	II-1
Beacons	II-1
Angle of Approach Indicators	II-5
Approach and Runway Lighting Systems	II-33
Miscellaneous	II-81

Human Factors Research	II-107
Pattern Recognition	II-107
Luminance and Visual Acuity	II-115
Dynamic Visual Acuity and Motion Perception	II-137
Size-Distance Judgments	II-157
Response Latency to Visual Stimuli	II-167
PART III: AUTHOR INDEX TO ANNOTATED BIBLIOGRAPHY	III-1

LIST OF FIGURES

<u>Title</u>	<u>Page</u>
FIGURE 1: BEACON DESIGN CONCEPT	I-3
FIGURE 2: TEE SYSTEM, PLAN VIEW	I-8
FIGURE 3: TEE SYSTEM, PILOT'S VIEW	I-9
FIGURE 4: VIGSLA SYSTEM, PILOT'S VIEW	I-11
FIGURE 5: CROSSED LIGHTS SYSTEM, PLAN VIEW	I-14
FIGURE 6: CROSSED LIGHTS SYSTEM, PILOT'S VIEW	I-15
FIGURE 7: IVALA APPROACH AND RUNWAY CONFIGURATION	I-22
FIGURE 8: THREE DUTCH TESTED APPROACH AND RUNWAY CONFIGURATIONS	I-24
FIGURE 9: NAFEC FLIGHT TESTED RUNWAY CONFIGURATION	I-26
FIGURE 10: NAFEC EXPERIMENTAL LANDING ZONE PATTERNS - I, II, III	I-27
FIGURE 11: NAFEC EXPERIMENTAL LANDING ZONE PATTERNS - E, F, G	I-30
FIGURE 12: NAFEC EXPERIMENTAL LANDING ZONE PATTERNS - K, F, J	I-32
FIGURE 13: SAN FRANCISCO INTERNATIONAL AIRPORT - CENTERLINE LIGHTING SYSTEM	I-36

**PART 1: SUMMARY OF OPERATIONAL TESTS
AND HUMAN FACTORS RESEARCH, 1959-1961**

PART 1: SUMMARY OF OPERATIONAL TESTS AND HUMAN FACTORS RESEARCH, 1959-1961

Operational Tests and Design Developments

Flight tests and simulated flight tests of airport marking and lighting designs during 1959-1961 were concentrated primarily on angle of approach indication systems and runway landing zone patterns. A few studies were conducted to assess airport beacon systems and single studies were reported which evaluated runway marking materials and runway distance-to-go signs. Summary descriptions of flight tests are presented in this section in three categories of airport marking and lighting design: Beacons, Angle of Approach Indicators, and Approach and Runway Lighting Patterns. Summaries of each design category are organized as follows: first, a brief review of the status of operational test developments as of 1958, then a description of new designs introduced during 1959-1961, and finally a description of procedures and results of flight tests conducted during 1959-1961. Operational tests of individual light units, runway signs, and marking materials are included in a fourth sub-section, Components and Materials. A fifth sub-section, Methodological Problems and Developments, is included as a discussion of problems and progress in research technique in flight tests of marking and lighting designs.

Beacons

Review of 1958 Status

By the end of 1958, several different types of beacon concepts had been developed and used as aids to the location of the airport and active runway. Rotating single beacons flashing green and white are accepted standards for identification of civil airports; split white and green, for identification of military airports. Beacons mounted on rotating turntables, rotating and counter-rotating beacons at runway ends had been used to identify the duty runway as well as to provide direction-of-approach guidance.

New Design Developments and Test Results

In the 1959-1961 interval, there has been additional work with two of these concepts; the airport identification beacon and approach beacons mounted on rotating turntables. The principal development in beacon design for airport identification and localization has been to increase the vertical angle of the beam. Lighting standards for beacons had been based on 1936 aircraft speeds and operating altitudes, and beacons were designed to provide identification information to pilots at relatively low altitudes. Solutions to this problem have tended to be modifications of existing beacons rather than the introduction of new design concepts. The Air Force, for example, has recently completed a beacon modification program, adjusting beacon filaments to provide a vertical beam coverage to 20,000 feet.¹

¹ Personal communication with Mr. G. K. Clement, Electrical Engineer, Department of the Air Force.

One new beacon design concept has been suggested to solve the identification problem for airports servicing a wide range of aircraft types. Beacon lights would be mounted in pairs on a rotating unit: one pair adjusted for low altitude coverage; the other pair adjusted for high altitude coverage (See Figure 1).

A - low altitude beacons
B - high altitude beacons

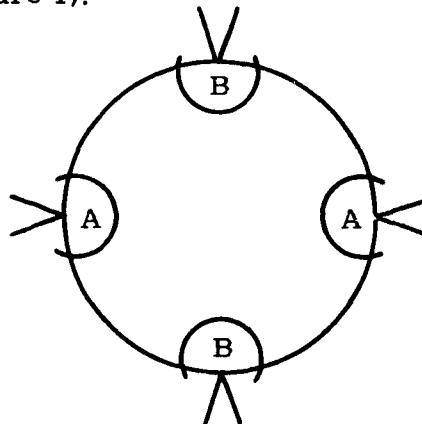


Figure 1: Beacon Design Concept

There has been recent emphasis on the possible use of beacon lights both as an airport identification aid and as an approach system. Such a configuration has the principal advantage of economy and has been suggested for the consideration of managers of small or secondary airports. An approach-beacon system had been tested by the Naval Air Test Center as early as 1950. More recent work by the National Bureau of Standards (National Bureau of Standards, 1959) at Arcata has provided additional data in support of the approach-beacon design concept. This system consists of two turntables positioned at 1,000 and 2,000 feet from runway threshold along extended centerline. Five beacons are mounted on each turntable. Pilots using this system reported that early identification of the duty runway was provided and, in addition, the system provided guidance for circling and for alignment with the runway on final approach.

As an identification and approach aid for airports where the terrain of the approach zone is such that a standard approach-beacon installation is not practical, a stub approach-beacon system was developed and tested at Arcata (National Bureau of Standards, 1959). The stub system consists of a single beacon and threshold wing bars. Pilots' comments indicated that it was much less effective than the standard approach-beacon system in providing alignment guidance although it was useful for downwind and base leg guidance for circling approaches.

Following the Arcata work, approach-beacon systems were installed by the Navy at Oceana, Virginia, and El Torro, California. No formal evaluations have been made of the system at these installations. Informal reports of pilots indicate that the system is less desirable than the complete national standard approach system.² The approach-beacon system, however, is not intended as a substitute for this high intensity, precision approach system; and with its obvious cost advantage and its demonstrated functional value in providing identification and alignment guidance, the approach-beacon system appears to be a reasonable solution to some lighting problems of secondary airports.

² Personal communication with Mr. R. K. Hartz, Head, Shore Based and Seadrome Section, Bureau of Ships, Department of the Navy.

Angle of Approach Indicators

Review of 1958 Status

Four major types of extra-cockpit visual aids to provide angle of approach indications had been tried as of 1958: Tri-Color, RAE (red-white) System, Australian Double Bar (PVG) System, and Navy Mirror Landing System.

The Tri-Color is a split filter beacon using a color code (amber, green, and red) to indicate, respectively, "high", "on glide path", or "low". The RAE System uses two-color light signals. A red-white combination indicates "on glide path"; red-red signals, "low"; and white-white signals, "high". Some direction of change in glide slope information is provided in the RAE System. As the pilot deviates above correct corridor, the red lights turn pink, then white; as he deviates below established corridor, the white lights turn pink, then red. This system has been referred to in the operational test literature by several designations: RAE System, Red-White System, Two-Color System, Angle of Approach Indicator (AAI), and Visual Glide Path Indicator (VGPI).

A double-bar system was developed by Australians R. W. Cumming and J. C. Lane. This system uses two pairs of light bars, one pair positioned on each side of the runway so that the pilot on the correct glide path sees the bars aligned. The bars are color coded so that misalignment of the bars can be interpreted as a "high" or "low" indication. The degree of misalignment and the rate of change of misalignment of the bars indicate degree and rate of displacement from ideal flight path. This system has been referred to by several designations which include: Precision Visual Glidepath (PVG), Amber System, Double-Bar Ground Aid (DBGA), Australian Cumming-Lane System, and Aeronaautical Research Laboratory (ARL) System.

The Navy Mirror Landing System also encodes glide path information by an alignment principle. Green light bars are fixed on either side of a mirror and a point source light is positioned so that its reflection on the mirror is aligned with the green datum bars when the pilot is on a correct glide slope.

New Design Developments and Test Results

During 1959-1961, there have been three new design developments with respect to angle of approach indicators. In addition, the RAE System has been accepted as the U. S. national and international standard and officially designated as the Visual Glide Slope Indicator (VGSI). The three new designs are the TEE Visual Glide Path (TVG) System, the Visual Glide Slope Landing Aid (VIGSLA) System, and the Crossed-Lights Optical Landing System (CLOLS). Test results with these three new designs and previously designed angle of approach aids are reported in this section.

TEE Visual Glide Path (TVG) - This system was developed by Australians J. R. Baxter and J. C. Lane as an alternative to the Cumming-Lane Double-Bar System of providing angle of approach information (Baxter, Cumming, Day, & Lane, 1960). The earlier presentation technique relied upon pilot judgment of degree of misalignment of the bars as an indication of degree of glide path deviation and used color coding as an indication of direction of the deviation. The TEE System presents either an inverted or upright "T" to indicate direction of glide path deviation. The extent of deviation can be judged by length of the leg of the "T". Red "fly up" lights become visible to the pilot when the aircraft is below the obstruction clearance plane.

The system consists of a transverse bar of white lights on each side of the runway and a set of 12 lighting units arranged in lines parallel to the runway lights and 100 feet outboard of them. The bar is positioned at the intercept of the ILS glide path with the ground or 900 feet from runway threshold in the absence of an ILS reference. For night use, there is a flush aiming light in the middle of the runway in line with the transverse bars (see Figure 2).

The bar and the light units form an upright "T" symbol on each side of the runway to specify "fly-up". An inverted "T" on each side of the runway signifies "fly down". The "on glide path" signal is a line of horizontal lights on each side of the runway, the leg of the "T" (light units) having disappeared. The cut-off of the light units are arranged so that the lights forming the leg of the "T" appear progressively as the pilot deviates further from the desired glide path (See Figure 3). This provides a scale of deviation similar to the scale of dots on the ILS cockpit instrument. This familiar presentation allows for ease of interpretation of the visual display. Furthermore, TVG avoid both color coding and elevated lights for which RAE and PVG Systems have been criticized.

The Aeronautical Research Laboratory, Melbourne, Australia (Baxter, Cumming, Day, & Lane, 1960), has conducted one field test comparing the merits of the new TEE System with the PVG and the RAE Systems. Approach profiles of test runs were calculated from theodolite records, pilots were asked to indicate their choice of systems by making pair comparisons, and unstructured interviews were held with the test pilots. Significantly smaller deviations from prescribed glide slope were found for TEE as compared with RAE and PVG systems. Pilot expressions of preferences also favored the TEE System.

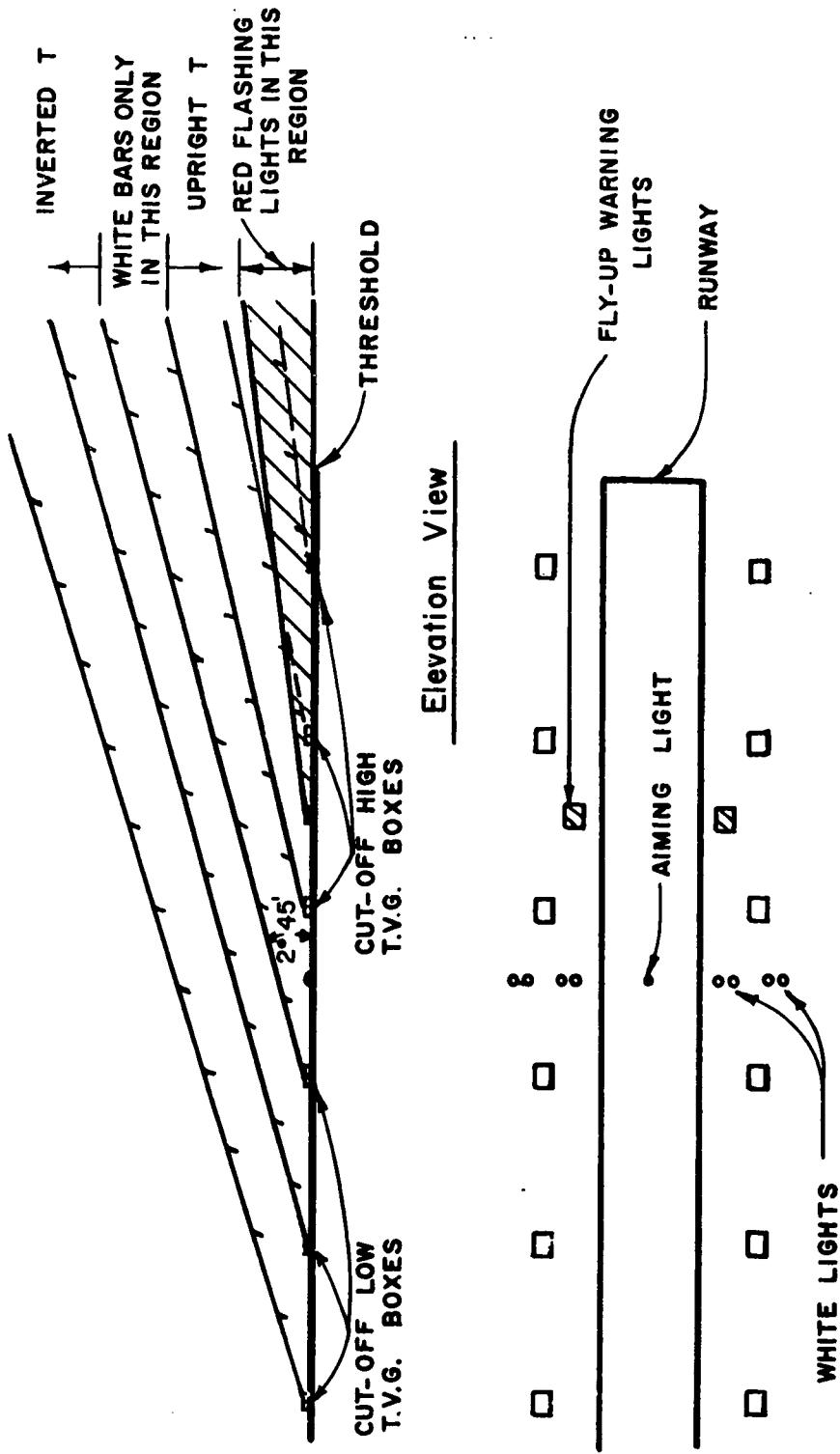
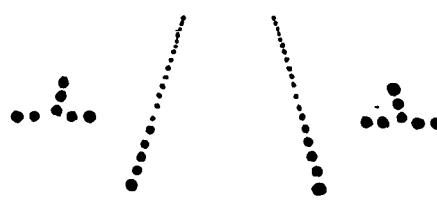
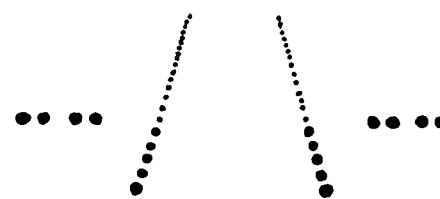


Figure 2: TEE System, Plan View

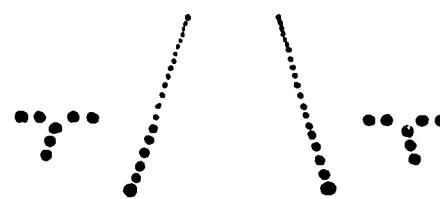
HIGH
FLY DOWN



ON GLIDE PATH



LOW
FLY UP



BELOW OBSTRUCTION
CLEARANCE PATH
FLY UP

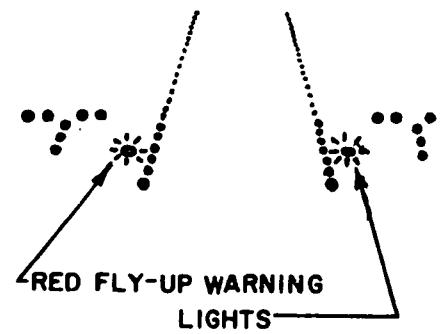


Figure 3: TEE System, Pilot's View

Visual Glide Slope Landing Aid (VIGSLA) System - The
VIGSLA System was developed by Western Air Defense Force, Air Defense Command, United States Air Force as an angle of approach aid for long, straight-in, power-on, final approaches at low glide slope angles under VFR conditions (Olson, 1959). The VIGSLA System contains two primary components (See Figure 4). The first component is a pair of panels, one on each side of the runway. These panels are lined up with the second component, a reference line painted on the runway perpendicular to the runway centerline. At 3,000 feet out on final approach, the panels subtend about the same visual angle as the ILS horizontal reference bar viewed at normal eye-to-instrument panel distance. The entire configuration, therefore, has indications and proportions similar to the ILS instrument signals with approximately the same order of accuracy as the ILS. The VIGSLA panels move up in relation to the runway reference line when the aircraft goes below the desired glide slope, and vice versa. The guidance principle involved in VIGSLA, it should be noted, is not novel. It is essentially the principle of the alignment of bars as employed in the PVG System.

Field tests of this system conducted at McChord and Hamilton Air Force Bases indicated several desirable features (Olson, 1959). One of the most important features noted is the ease of interpretation of the system and the facility with which a pilot can switch from ILS cockpit instruments to visual contact. VIGSLA, the authors claim, is useful for a wide range of jet aircraft types--F-89, F-101, F-102, and F-104 aircraft were used in the flight tests. The system, over the entire test period of 6 months, required very little maintenance. The low cost of the system and the little maintenance requirement make it a potentially desirable marking design for small airports. Its usefulness, of course, is restricted to daytime conditions.

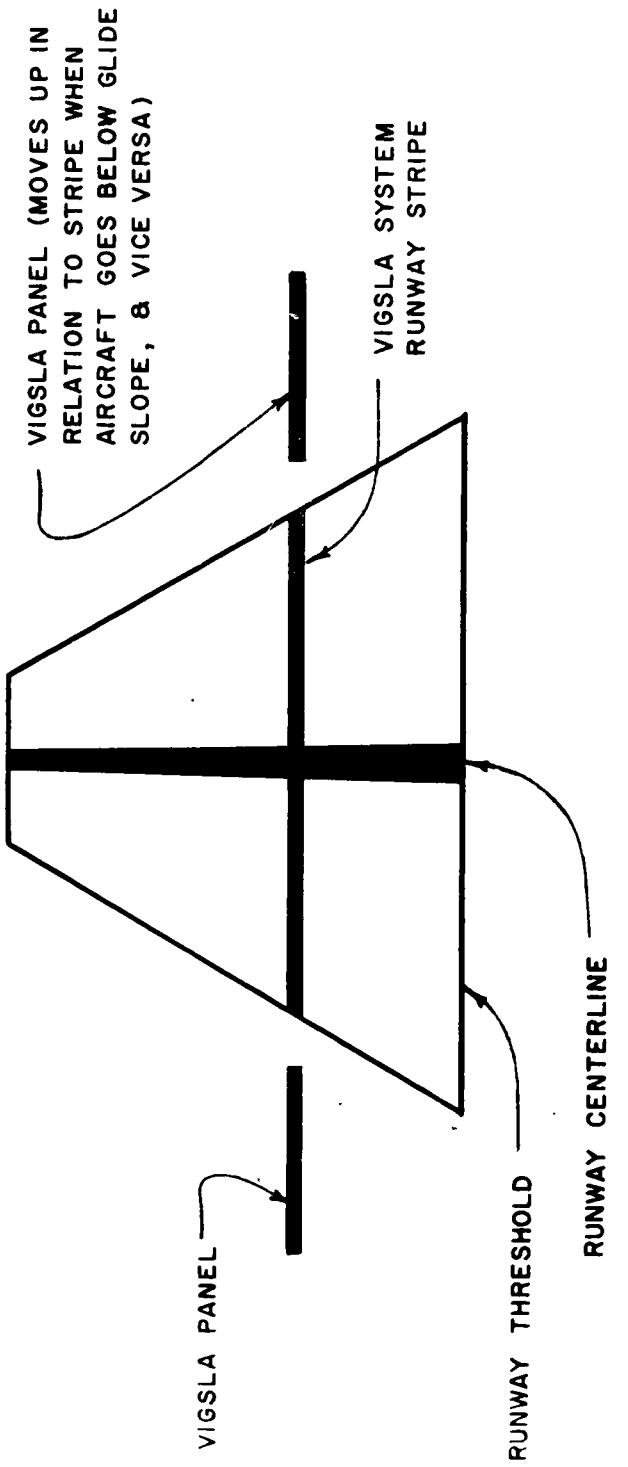


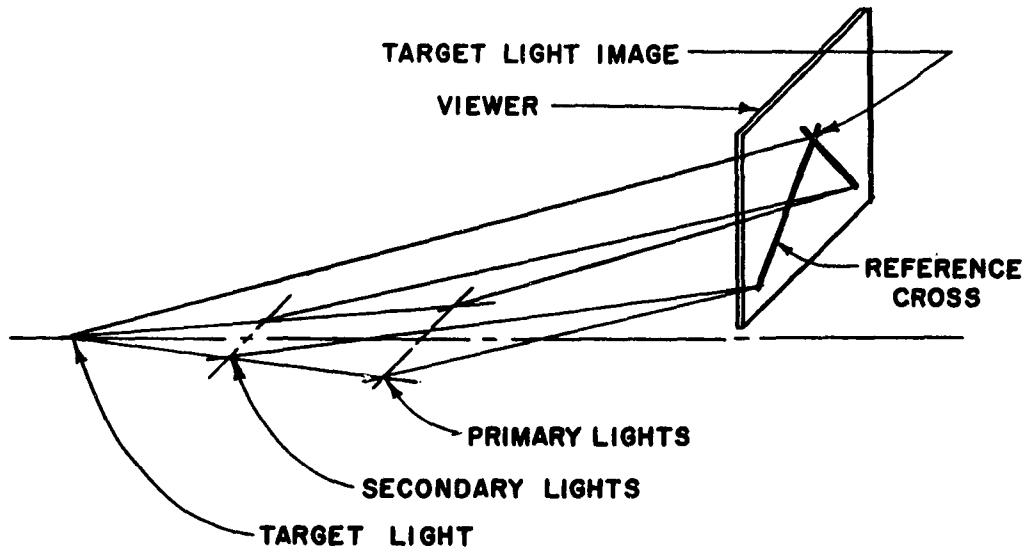
Figure 4: VIGSLA System, Pilot's View

Crossed-Lights Optical Landing System (CLOLS) - The
CLOLS was designed to give improved glide path information to fleet aircraft landing on carrier decks (U. S. Naval Air Test Center, 1960). The possibility exists for its adaptation to airports. The system consists of a viewing device located in the airplane and a display of light sources located in the landing area. Cross hatch lines are inscribed on the surface of the viewing screen. The image of the point light sources is spread into lines which form reference cross intersections.

The deck display consists of five lights: two primary, two secondary, and one target light. The primary lights are the main cross-generating lights. The secondary lights provide glide path information when the aircraft is between the ramp and touchdown point. The target light represents the touchdown point and is sighted at the apex of the generated cross (See Figure 5). This indication represents the correct glide slope. When the target light is above the apex of the cross, the deviation from ideal glide slope is in the "too low" direction and vice versa (See Figure 6).

In flight tests of the CLOLS at the U. S. Naval Air Test Center, Patuxent River, Maryland (U. S. Naval Air Test Center, 1960), thirty-one day and seven night flights were flown. Nine different types of fleet aircraft were flown in approaches under a range of visibility conditions. The tests indicated that the display gave adequate glide path information to touchdown. The pilots continued to receive sufficient glide path information even when flying at extreme vertical deviations. Heading alignment with the carrier deck was reported as aided by the CLOLS display. The pilots reported imagining that the angle formed by the crossed lines were bisected and that they then flew that bisecting line to the apex of the angle. Problems experienced with this system were

its narrow lateral guidance limits and the confusing effects of extraneous lights creating crossed lines.



Elevation View

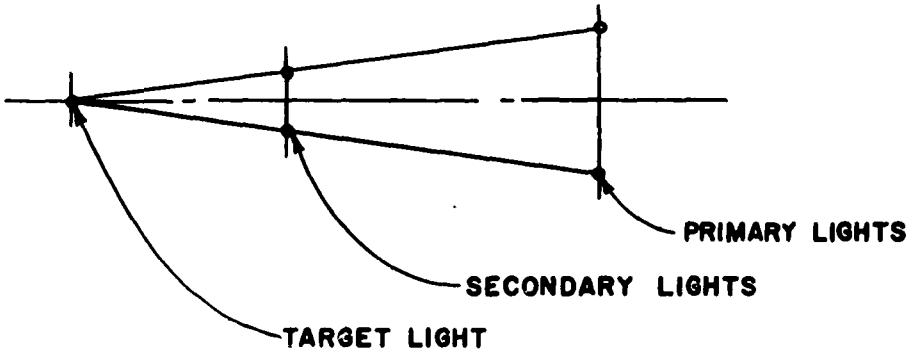


Figure 5: Crossed Lights System, Plan View

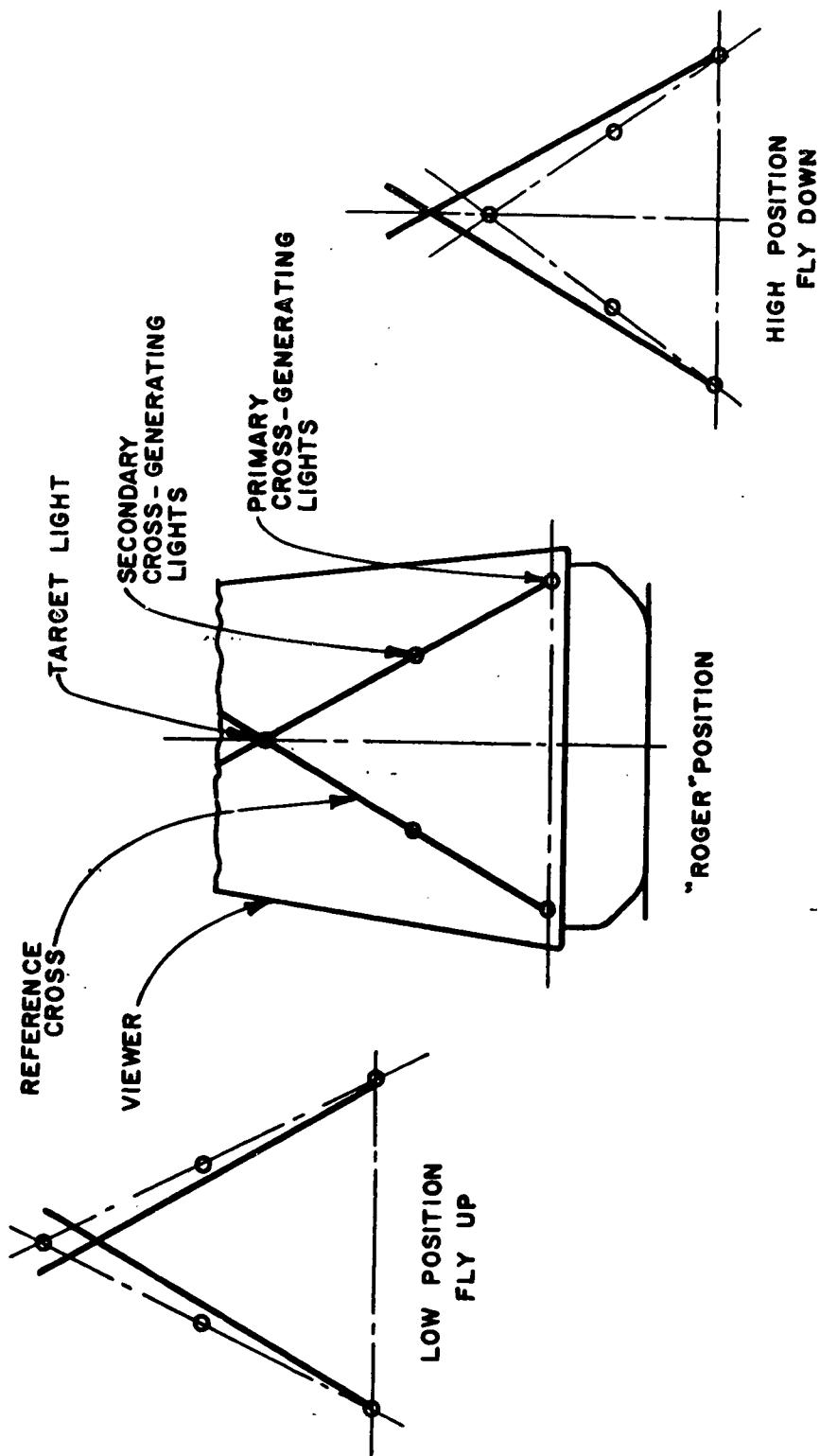


Figure 6: Crossed Lights System, Pilot's View

PVG vs. RAE - In November 1958, night flight tests were conducted at Mangalore Airport, Australia to compare PVG and RAE Systems (Day & Baxter, 1959). Twelve commercial airline flight captains whose flight experience ranged from 7,000 to 20,000 hours participated in the tests. Eight of the pilots were employed by local Australian airlines (Trans Australia and Ansett-ANA); the other four pilots were with Qantas Empire Airways. The test aircraft was a DC-3 and each pilot flew three approaches to each system. Questionnaire data were obtained after each approach and theodolite recordings of the flight profiles were taken.

Of 157 responses to questionnaire items concerning the relative advantages of the PVG and RAE Systems, 63 favored PVG, 24 favored RAE, and 70 rated the two to be equal. When asked for an overall preference between the two systems, nine pilots favored PVG and three pilots favored RAE. No statistical evaluation of these data was performed and the authors presented their results as suggestive rather than conclusive.

Analysis of the theodolite recordings indicated no statistically significant differences in flight profiles for approaches to PVG or RAE Systems.

Between March 1958 and April 1959, flight trials to compare PVG and RAE angle of approach aids were conducted at the Royal Aircraft Establishment, Bedford, England (Morrall, 1960). Four highly experienced pilots of the Blind Landing Experimental Unit participated in the flight tests and used four types of aircraft: Devon, Varsity, Meteor, and Javelin. Approximately 250 approaches were flown to each system, 60 percent in daylight and 40 percent in night conditions. Most approaches (70 percent) were made in visibilities of 1 1/2 mile or greater slant visual

range and ceilings of 450 feet or greater. A small number of approaches (6 percent) were flown in low visibility conditions - slant visual range of 600 yards or less.

Initial approaches were photographed and flight profiles examined. Variations from standard 3 degrees glide slope were on the order of .25 degrees and this measure was abandoned as a test criterion in favor of qualitative evaluations by the pilots. Pilots made overall evaluations of the two systems in terms of ease of identification, ease of interpretation, roll and azimuth guidance, and guidance during turn onto final approach as well as evaluating their effectiveness as angle of approach aids.

The summary report of the four pilots was that the RAE System is the "more satisfactory and comprehensive visual approach indicator" (Morrall, 1960, p. 15). Reported advantages of the RAE System over PVG were that it was more sensitive at long range and provided useful guidance down to flare-out.

Five types of visual glide path indicators were installed and flight-tested at the National Aviation Facilities Experimental Center (NAFEC), Atlantic City, New Jersey: Westinghouse Tri-Color, Navy Mirror, USAF Interim Mirror, PVG, and RAE (Griffith, 1960). After 6 weeks of flight tests which included 400 approaches, PVG and RAE Systems were concluded to be most useful of the five systems and an additional 6 weeks of flight tests were conducted to compare these two.

Over 100 military, commercial, and private pilots volunteered for the flight-test program although questionnaire records were completed by 62. Twenty-six types of aircraft, from Piper Tri-Pacer to Boeing 708, were flown in the tests, and pilots varied in flight experience from 500 to 20,000 hours. Test flights were flown in both

day and night conditions and most approaches were in weather conditions above 1,500-foot ceiling and 5 miles visibility. Contraves Phototheodolite records defined flight profiles for all test flights. Time required to maneuver to glide path after simulated breakout was recorded for two highly experienced pilots. One pilot made a series of landings both with and without angle of approach aids and dispersions of touchdown points were compared.

Records of touchdown point dispersions yielded inconclusive results and the test pilot reported that angle of approach indicators have no influence on touchdown point. Records of time required to maneuver to glide path yielded inconclusive results. No significant difference in time to maneuver to glide path was observed when flying to the two systems. There were, furthermore, no significant differences in aircraft flight paths in approaches with PVG and RAE Systems.

Tabulation of pilot questionnaire responses favored RAE over PVG. Fourteen questions were included in the questionnaire which asked for comparisons on separate aspects of the PVG and RAE Systems. RAE was judged to be better on eleven of these items, PVG was judged better on two items, and they were judged equal in one aspect. When asked for an overall evaluation, 36 pilots expressed preference for RAE, 22 pilots preferred PVG, and 2 pilots reported no differences between the systems. On the basis of these results and considering maintenance and installation costs, the RAE System was recommended as a U. S. national standard.

Other Angle of Approach Systems - The flight-test program at NAFEC (Griffith, 1960) was concentrated on a comparison of RAE and PVG Systems but did include some alternative systems in the early test phase. A Tri-Color System, a Navy Mirror Landing System, and a USAF

Interim Mirror System were evaluated in the preliminary 6-week flight test and then eliminated from further consideration since they all offered inadequate guidance in some respect.

The Navy Mirror Landing System contained no indication as to whether to fly up or down when pilot deviated more than 3/4 of a degree from glide slope. Furthermore, moisture on the mirror produced an intolerable degradation of the glide slope signal.

The USAF Interim Mirror System was relatively insensitive to changes in altitude due to the short distance between light source and datum bars. It was found possible to receive an "on glide path" signal 3 nautical miles from touchdown while at an altitude of only 40 feet.

The Westinghouse Tri-Color System was difficult to use in daylight conditions; some pilots did not pick up signal until over the threshold. Furthermore, color definition deteriorated under conditions of precipitation or when moisture collected on the lens.

Approach and Runway Lighting Patterns

Review of 1958 Status

During the period 1946-1958, a wide variety of approach lighting systems had been flight-tested. These included one or more varieties of parallel rows or multiple row systems, single row systems, composite systems, a slope-line system, and the Calvert System. The centerline approach system concept, initially introduced by ALPA in 1948, was eventually accepted as the U. S. national standard in 1958. This centerline lighting system, known as Configuration A prior to its adoption as the national standard, is composed basically of 28 centerline bars of white lights with a condenser discharge unit on 100-foot centers beginning 3,000 feet from runway threshold, a terminating bar of red lights 200 feet from threshold, red pre-threshold wing bars, and a white crossbar 1,000 feet from threshold. With the adoption of Configuration A as the national standard, flight tests of approach systems in this country were virtually discontinued and interest became focused upon the problems of landing zone lighting.

In 1955, the national standard for runway edge lights was established. Lights were to be spaced uniformly along the runway edge and the spacing interval was not to exceed 200 feet. The development of semi-flush lights for installation in the runway surface stimulated efforts to provide additional heading and altitude guidance information by runway light patterns. Flight tests of runway lighting patterns were begun in Great Britain and the Netherlands and followed up in this country by flight tests at Andrews Air Force Base and Dow Air Force Base. In both cases a narrow gauge pattern was used. This pattern consisted of short bars of flush light units placed symmetrically on either side of the runway centerline

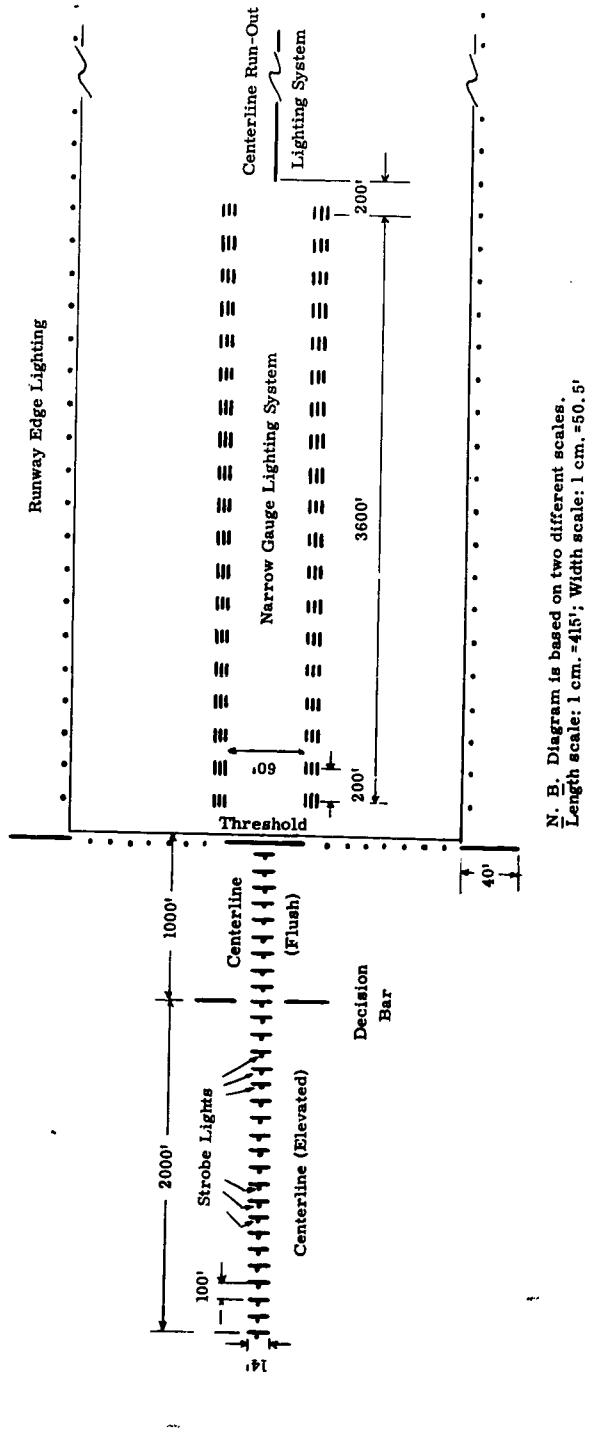
on 60 or 75-foot centers (30 or 37.5 feet on either side of centerline).

One alternative to the illumination of the runway surface by patterns of flush lights was a floodlighting arrangement installed for test purposes at Andrews Air Force Base and later at Washington National Airport.

New Design Developments and Test Results

IVALA System - Early in 1959, the U. S. Air Force installed and flight-tested at Dow Air Force Base a combined approach and runway lighting system, the Integrated Visual Approach and Landing Aids (IVALA) System (Strong, 1959). This integrated system consisted of a modified national standard approach lighting system. The last 1,000 feet of the centerline were flush lights. On either side of the centerline, three pairs of transverse roll guidance bars were placed at 500, 1,000 and 1,500 feet from threshold. The runway lighting system consisted of a 60-foot narrow gauge of flush lights for 3,000 feet and a flush centerline run-out lighting system for the remaining 3,800 feet (See Figure 7).

The major results of the flight tests were recommendations to eliminate the transverse roll bars and the red termination bar. Sufficient roll guidance was obtained from the centerline and the transverse bars were found to materially alter the appearance of the basic centerline approach system and to complicate the pilots' interpretative problems. The red termination bar was found to elicit negative pilot reactions at a critical time in the approach as the color red is typically used to indicate obstructions or other danger conditions. Minor adjustments of the narrow gauge light units and changes in spacing of the



N. B. Diagram is based on two different scales.
 Length scale: 1 cm. = 415'; Width scale: 1 cm. = 50.5'

Figure 7: IVALA Approach and Runway Configuration

centerline lights were recommended; but, for the most part, the integrated approach and runway system was found to be compatible and to provide effective guidance for both approach and landing phases. On the basis of this test, the U. S. Air Force has accepted IVALA as a design standard for approach and runway lighting.

Netherlands Systems - In early 1961, Van O'osterom (1961) reported results of flight tests of three integrated approach and runway lighting systems (See Figure 8). Two of the systems, labeled by Van O'osterom as "ALPA" and "CALVERT" Systems, were similar in design. The "ALPA" System was a centerline approach and narrow gauge runway lighting system. The "CALVERT" System was essentially the same except for the addition of crossbars at 500-foot intervals along the approach centerline. The third configuration tested was a proposed "NETHERLANDS" System. As can be seen from Figure 8, the "NETHERLANDS" System consisted of an approach configuration identical to the "CALVERT" System for the outer 2,000 feet; the inner 1,000 feet included three longitudinal lines of lights. The runway pattern was composed of longitudinally oriented bars in a narrow gauge and as runway edge lights.

One aspect of the flight path records indicated a significant difference among the systems tested. Aircraft altitude at threshold was closer to the prescribed ideal altitude for the "NETHERLANDS" System than for the "CALVERT" System. The study is somewhat unique in that a pilot control measure and a physiological measure were recorded. Both of these measures were significantly different between approaches to "ALPA" and "CALVERT" Systems. These results were not interpreted by the authors, however, in terms of their implications to the designs tested.

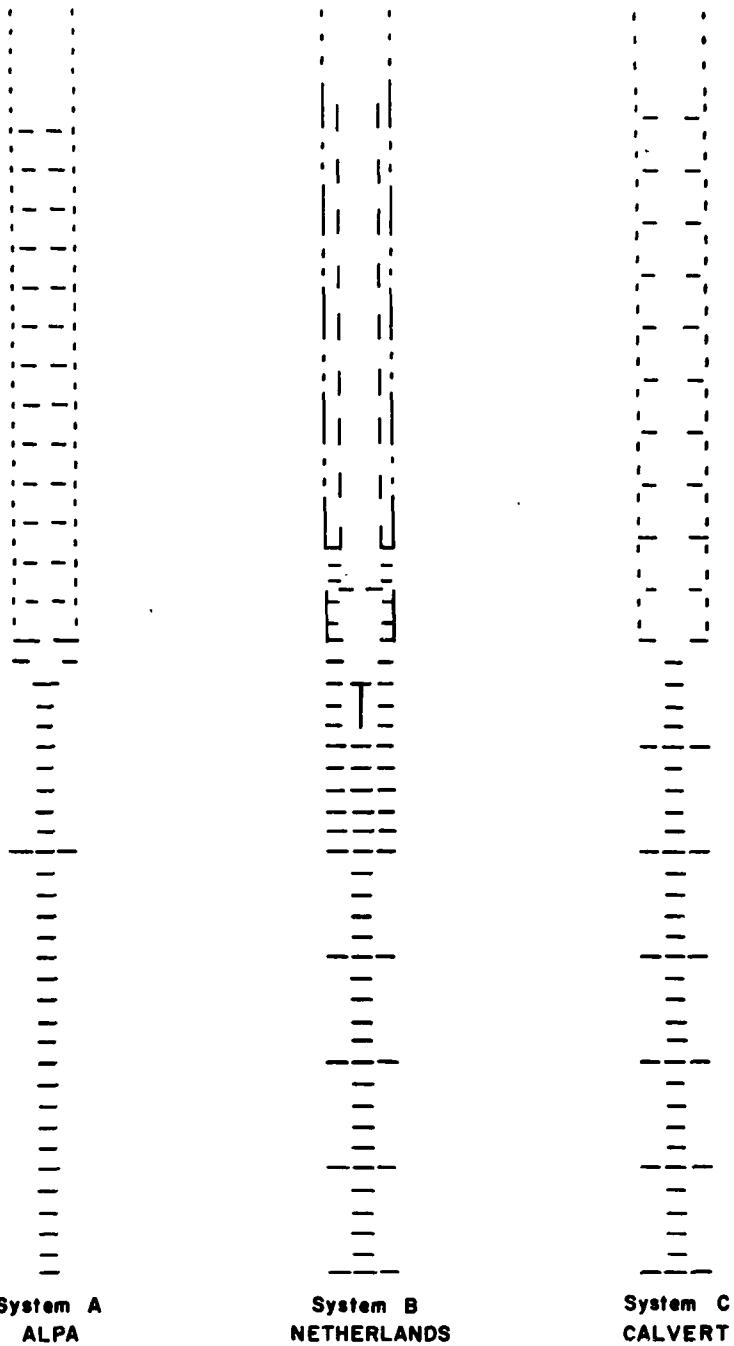


Figure 8: Three Dutch Tested Approach and Runway Configurations

NAFEC System - Five runway lighting patterns were flight-tested at FAA's Atlantic City test facility, National Aviation Facilities Experimental Center (NAFEC). Each of these patterns was a variation of centerline and narrow gauge lighting. Thirty pilots and several different aircraft types were used in the flight tests. Tests were conducted at night under simulated fog conditions. Smoke generators along the runway edge provided the fog simulation. Theodolite records were taken during the test but not used in the evaluation since recordings of the aircraft's track could not be made through the smoke. Pilot ratings of the adequacy of roll, heading, and altitude guidance were recorded after the test runs and used along with engineering considerations to select the best pattern (See Figure 9). This pattern was recommended for installation at Dulles International Airport, Chantilly, Virginia.

NAFEC Simulated Patterns - Three studies (McKelvey, Brown, & Ontiveros, 1961a; McKelvey, Brown, & Ontiveros, 1961b; McKelvey and Ontiveros, 1961) have been conducted at NAFEC which compared the relative effectiveness of experimental runway landing zone patterns. Each of these studies was conducted with the Dalto/P-3A Simulator Complex.

In the first study (McKelvey, et al., 1961a), three landing zone lighting patterns were compared: Configuration I, Narrow Gauge with Centerline; Configuration II, Narrow Gauge with Parallel Rows and Cross Bars; Configuration III, Crossbar and Cross-Pip System (See Figure 10). The pilot landing task was conceptualized as one of making relatively minor control corrections in heading, pitch, roll, and thrust to compensate for displacements of the aircraft from ILS localizer and glide path instrument indications upon transition from instrument to contact flight. Functions of the runway lighting pattern were derived from this concept of the pilot task. The lighting pattern must provide

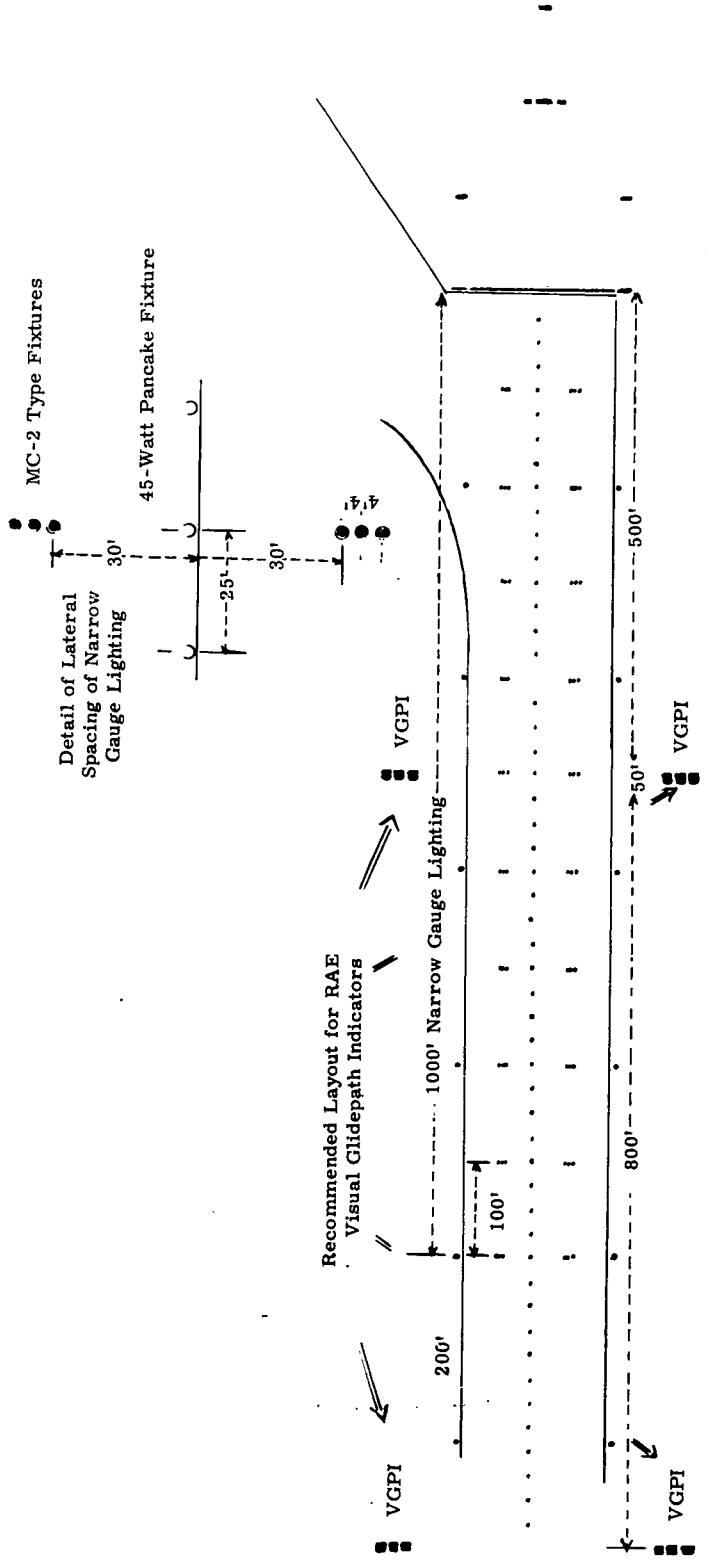
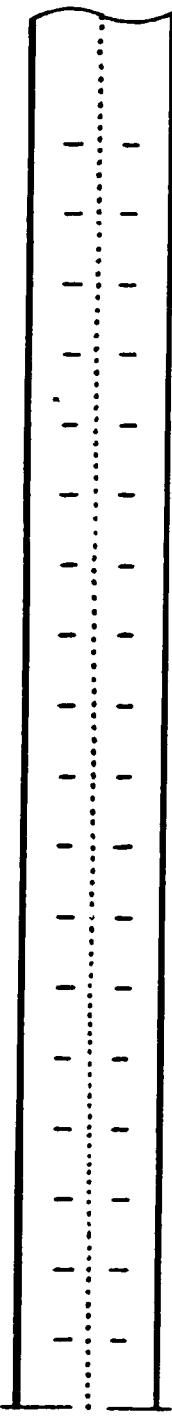
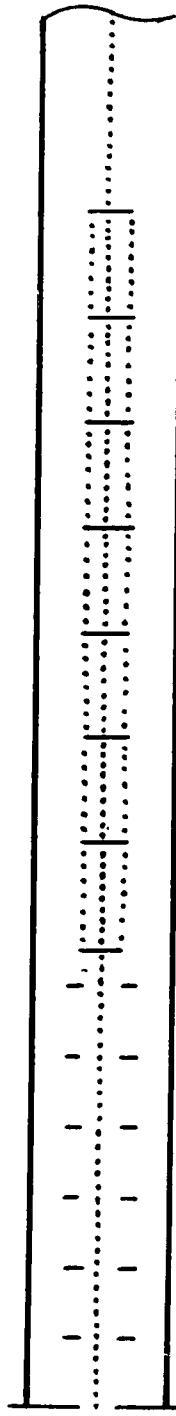


Figure 9: NAFEC Flight Tested Runway Configuration

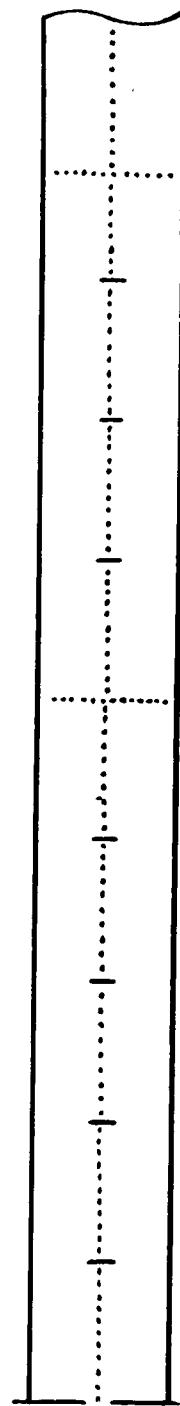
Figure 10: NAFEC Experimental Landing Zone Patterns – I, II & III



CONFIGURATION I - NARROW GAUGE WITH CENTERLINE



CONFIGURATION II - NARROW GAUGE WITH PARALLEL ROWS AND CROSSBARS



CONFIGURATION III - CROSSBAR AND CROSS - PIP SYSTEM

visual guidance for correcting limited displacements in roll, pitch, and heading-line-of-flight, for correcting error in rate of descent, and for indicating time of flare-out, touchdown, and roll-out steering guidance.

Twelve experienced pilots were given a one-hour familiarization run on the simulator prior to the experimental test runs. The "aircraft" was then positioned 5 miles beyond the outer marker with ceiling and RVR conditions 400 feet and 1,300 feet respectively. Transition from instrument to visual contact was programmed upon passing the middle marker about .6 miles from threshold. Displacements in roll, pitch, and heading-line-of-flight were introduced upon break-out. The pilots' task was to execute the required correction maneuver in response to the visual pattern which the runway lighting configuration provided. Each pilot made eight approaches to each of three patterns and were asked to state a preference for one of the patterns after two, four, six, and eight runs on each of the patterns.

An observer recorded adequacy of the pilot adjustments in pitch, roll, and heading-line-of-flight by noting their occurrence or non-occurrence. Timeliness of the maneuver executions was scored as either completed or not completed before flare-out. Vertical speed at touchdown was scored as leveling off "high", "low", or "on". Adequacy of steering guidance on roll-out was scored with reference to the runway centerline. Adequacy of visual guidance for longitudinal positioning at touchdown was determined to be "long", "short", or "on" by recording time of the "tire squeal" from the simulator.

Statistical analysis of the performance data indicated significant differences among the three patterns in providing guidance for heading-line-of-flight and longitudinal positioning. The direction of these and other non-statistically significant differences ranked the

patterns I, II, III in descending order of effectiveness. Analysis of the pilot preference data resulted in an identical ranking of the systems.

In a second NAFEC simulator study (McKelvey et al, 1961b), three experimental landing zone lighting patterns and a conventional runway edge lighting pattern were compared. The patterns were coded as follows: Configuration E, Distance Coded Discontinuous Longitudinal Array; Configuration G, Narrow Gauge with Lateral Barrettes; and Configuration N, Conventional Runway with Standard Edge and Threshold Lighting (See Figure 11).

Roll, pitch, and heading-line-of-flight displacements were introduced into the simulator and appropriateness of pilot control reactions was scored by an observer as in the first study (McKelvey et al., 1961a).

Twelve pilots from the Flight Operations Branch at NAFEC were presented with three maneuver problems in the Dalton Simulator. The problems were defined by roll, pitch, and heading-line-of-flight displacements and had to be solved, as in the previous NAFEC simulator study, by corrective responses based on the pilots' interpretations of the visual pattern presented by the runway lighting configurations. Each pilot made six approaches to each lighting configuration with each maneuver problem for a total of 72 approaches. Following a block of trials for a given maneuver problem, pilots were asked to state a preference among the lighting patterns.

Analysis of pilot performance data indicated no significant differences among the patterns either in correcting for roll and heading-line-of-flight displacements or in longitudinal positioning at touchdown. Experimental patterns, F and G, were moderately more effective than the conventional pattern, N, in providing guidance for

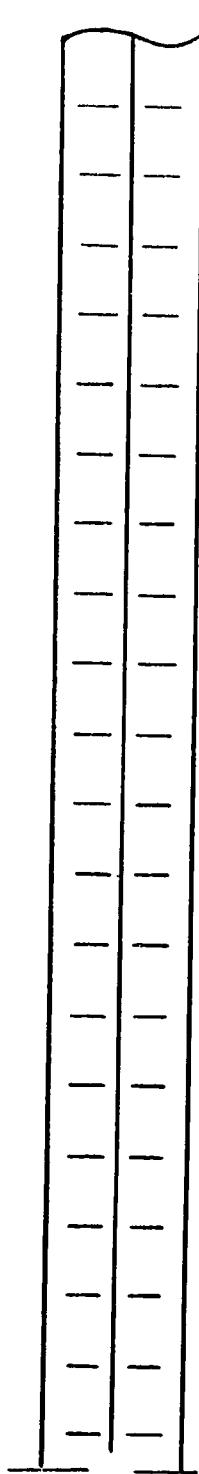
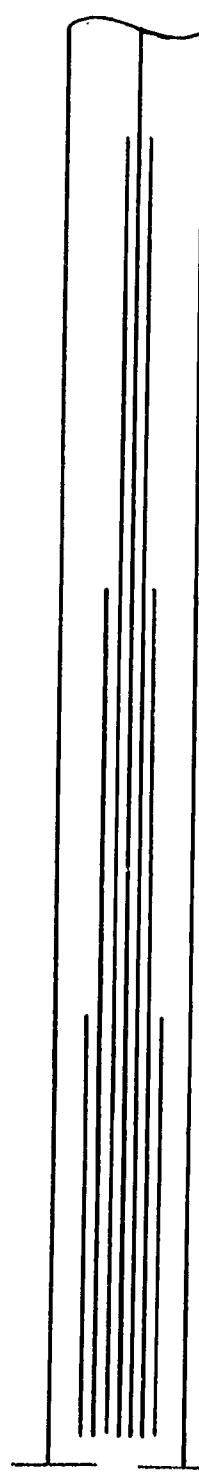
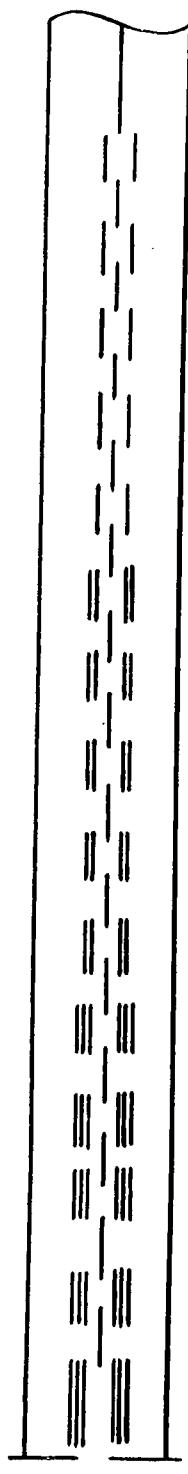


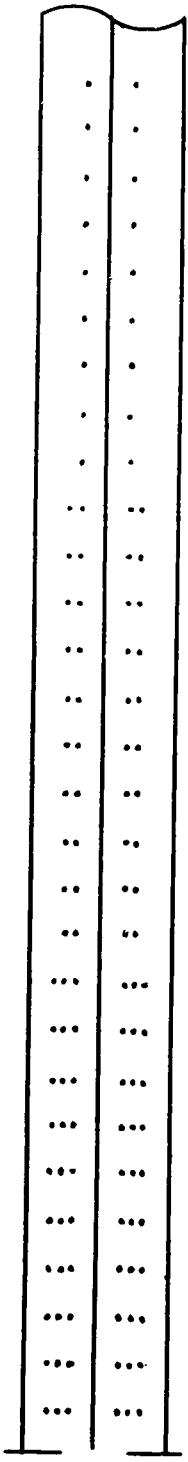
Figure II: NAFEC Experimental Landing Zone Patterns - E, F, G

attitude control and for attaining optimal vertical speed at touchdown. Experimental pattern, E, was also more effective than the conventional pattern, N, in providing the information necessary to attain an optimal vertical speed at touchdown. While experimental patterns were more effective sources of guidance information than the conventional edge lighting, there were no significant differences among the experimental patterns in any of the performance measures recorded.

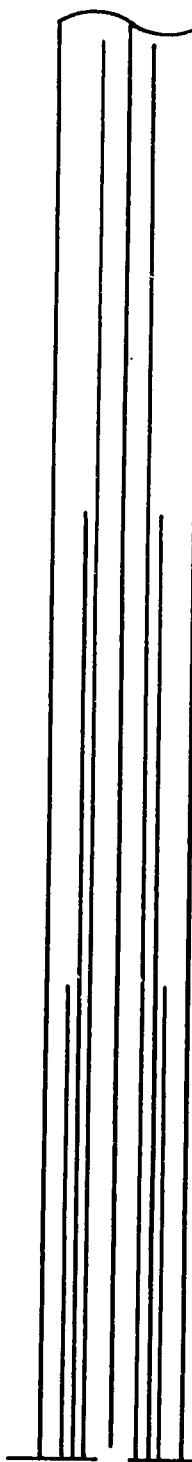
A third study (McKelvey & Ontiveros, 1961) was conducted to further explore distance coding in runway landing zone patterns. Three patterns were designed which varied in degree of longitudinal spacing of the distance coding 3:2:1 arrays and in the regularity of the spacing. In Configuration K, the light units were separated by 100 ft. throughout the 3,000 ft. pattern. Light units were separated longitudinally by 25 ft. throughout the pattern in Configuration F. Configuration J was an irregularly spaced pattern: units were placed at 100-foot intervals for the first 1,000 ft. of the pattern, then at 25-foot intervals for the remaining 2,000 ft. (See Figure 12).

Experimental procedures similar to those of the first study (McKelvey, et al, 1961a) were followed. Rotational displacements were introduced into the flight simulator; the pilot's task was to correct these deviations by appropriate maneuvers and complete the landing; adequacy of the maneuvers was scored by an experienced observer.

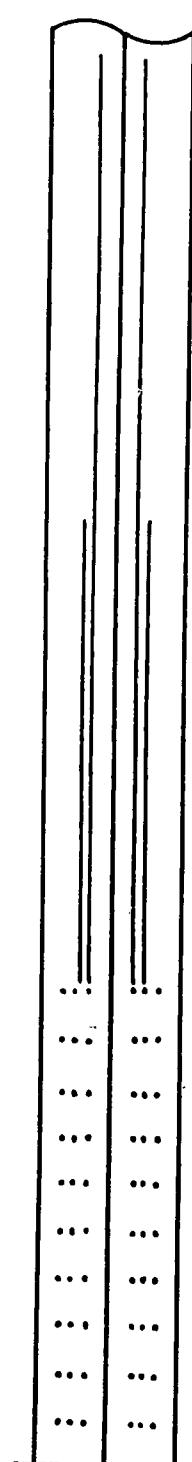
Analysis of performance data suggest that the closely spaced arrays of Configuration F are superior to both the wide and mixed arrays of Configurations K and J in providing visual guidance for correcting displacements on flight axes and for controlling rate of execution of corrective maneuvers. The patterns were equally effective in providing information for control of rate of closure, vertical speed, and longitudinal positioning at touchdown.



CONFIGURATION K.—DISTANCE CODED 3:2:1 WIDE-SPACED ARRAY



CONFIGURATION F.—DISTANCE CODED 3:2:1 CLOSE-SPACED ARRAY



CONFIGURATION J.—DISTANCE CODED 3:2:1 MIXED-SPACED ARRAY

Figure 12: NAFEC Experimental Landing Zone Patterns — K, F, J

Analysis of pilot preference data, although not statistically significant, are in the direction of the performance data and support the conclusion that Configuration F is a more effective pattern than K or J.

Additional research with distance coding has been recently conducted by McKelvey and Ontiveros to explore the interaction effects of various visibility levels and degrees of longitudinal spacing of the light arrays. A report of this work is expected in early 1962. The results of this work suggest that a 50-foot separation interval between lights in the longitudinal arrays is optimal over a range of visibilities. At a very low visibility (850 ft. RVR), the more closely spaced arrays (25 ft. separations) appear most effective; and at the high visibility (1300 ft. RVR) the wider spacing (100 ft.) is most effective. These extreme spacings, however, introduce error in longitudinal positioning at touchdown when the visibility conditions are reversed. With close spacing and high visibility, pilots tend to overshoot; with wide spacing and low visibility, pilots tend to undershoot. Pilots, furthermore, expressed preference for the 50-foot spacing and, in general, found distance coding a useful feature of the landing zone pattern.

The distance coded landing zone lighting patterns illustrated in Figure 12 have been compared with a conventional narrow gauge pattern in a recent flight test at NAFEC. A report of this work by Gates and McKelvey is anticipated in early 1962. Experimental procedures and criteria developed for the earlier simulation studies (McKelvey, et al, 1961a, 1961b, 1961c) were implemented in the field test environment. Seventeen pilots flew six approach and landings to each of the four landing zone patterns. Significant differences were found among the patterns in terms of a measure of longitudinal positioning of the aircraft at touchdown. The close-spaced (25 ft.) distance-coded system was most effective in providing guidance for touchdown positioning, the non-coded system

was least effective, and the mixed-spaced system was more effective than the wide-spaced system. Pilot expressions of preference ranked the four patterns in an identical order. Differences between distance-coded systems, as a function of longitudinal spacing, were small, however, and the authors expressed the belief that the conventional narrow gauge pattern with 3 light barrettes at 100 ft. intervals could easily be distance coded by deleting the outer lights to form successive 1,000 ft. segments (Configuration K of Figure 12).

This series of simulator and field investigations of distance-coded runway landing zone patterns is an important development from the viewpoint of methodology in the research and development cycle of airport lighting design. The systematic identification of pilot tasks and associated information requirements; the logical development of task-related criterion measures for evaluating lighting patterns in terms of the guidance categories they are designed to provide; the screening of procedures, measures and lighting patterns through simulator research; and finally the flight test designed to follow through, in an operational flight environment, the base of information previously developed in the laboratory - this sequence of steps is in marked contrast to the characteristic trial-and-error approach of a few years past.

Apart from its methodological importance, the content results of both simulator and flight test research have compelling implications for design decisions. The utility of distance-coded landing zone patterns has been supported by research in both simulator and operational environments, and in terms of measures of pilot performance as well as preference. Distance-coded light arrays can easily be added to a conventional narrow gauge pattern such as has been recommended by the Air Force for installation at military airfield and which is anticipated to be recommended by FAA as a national standard.

Centerline System - During the winter of 1959-1960, flight evaluations of a runway centerline lighting system were conducted by Finch and Horonjeff (1960) at San Francisco International Airport. This system is composed of closely spaced, low-wattage light sources and was initially installed and flight-tested during the winter of 1958-1959 (See Figure 13).

Flight questionnaires were distributed to airlines for use by selected pilots, and control tower personnel were asked to obtain pilot comments about the centerline lights during low visibility conditions. Records were kept as to the number of times low, medium, or high brightness settings were requested by pilots. For 71 landings, a low setting was requested on 4 occasions, a medium setting on 34, and a high setting on 33. Principal conclusions from the questionnaire data were as follows:

Pilot reactions were favorable to the system in night and semi-dark conditions.

Pilots felt the system to be of questionable benefit in day conditions with 200 feet or higher ceilings.

More testing is needed in low visibility conditions.

Pilots did not complain of roughness when landing on units or on roll-out.

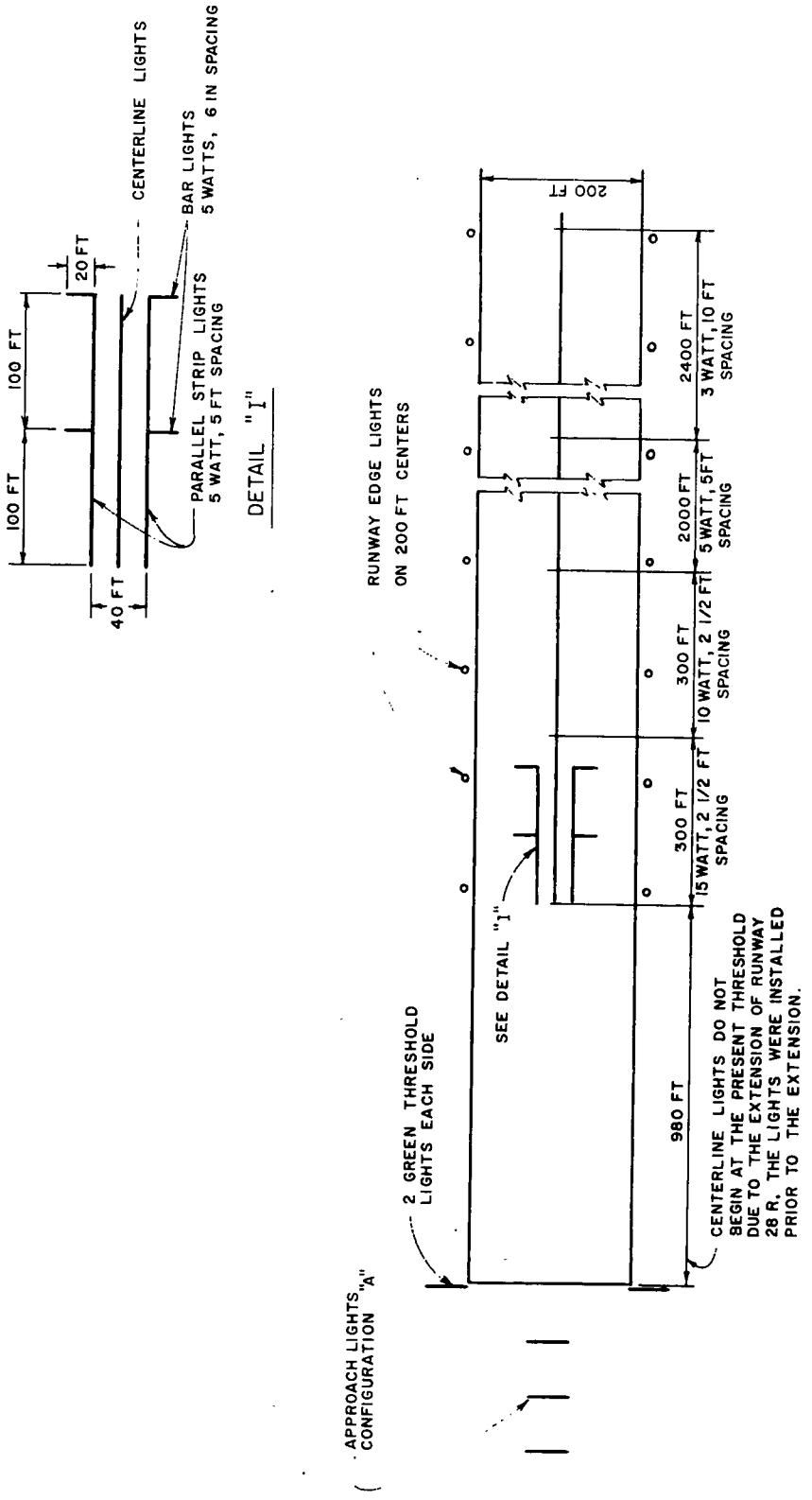


Figure 13: San Francisco International Airport – Centerline Lighting System

Components and Materials

Flush Light Units

Engineering development of flush light units continues to receive attention. Engineering problems appear formidable due to the many conflicting and apparent mutual incompatibilities of desirable features. The lights must be flush (or nearly flush) with the surface but at the same time visible through snow and water; they must be able to withstand repeated aircraft tire impact and at the same time contain transparent materials (glass or a plastic); they must emit light at particular angles and at the same time avoid deep dirt, snow, and water-collecting wells.

Flight tests of systems, such as those conducted by Finch and Horonjeff (1960) and by Strong (1959), included evaluations of flush lights and recommendations for improving them. A theoretical comparison of "blister" and "pancake" lights prepared by Sparke (1961) appeared to favor use of pancake lights for runway patterning.

Gas Light Units

Two articles (Gas, 1961; Gas Age, 1959) described the use of gas light units as runway lights. The use of gas units has been limited to small airfields, servicing non-commercial air traffic. Airports using these units appear to be located near to sources of low cost gas supplies and the principal advantages cited are low installation and maintenance costs. In addition, lights of this type emit a soft glow which may eliminate problems of glare.

Runway Distance Markers

Two developments are in progress in this area. Simeroth and Davis (1960) tested internally illuminated runway distance markers and compared them with standard designs. Visibility at night was greater for the internally illuminated sign than for the standard type.

FAA has work in progress to develop a frangible material for constructing distance-to-go signs.³ A range of synthetic materials are being considered and field tests at NAFEC can be anticipated.

Runway Marking Material

A National Bureau of Standards study (Vaughan, 1959) evaluated, in operational conditions, eight types of runway marking materials. Tested materials were as follows: masonry paint with beads, traffic paint with beads, traffic paint, traffic paint with "high-index" beads, masonry paint, cemented plastic material with imbedded beads, retro-reflective aggregate, and thermosetting plastic. Results of operational tests led to two major conclusions: first, traffic paint with beads, traffic paint with "high-index" beads, and retro-reflective aggregate were best for all-purpose marking; second, because of the layers of tire rubber which accumulate in the touchdown zone, the best material for marking this area is the cheapest retro-reflective material available.

³Personal communication with Major John R. Dart, Bureau of Research and Development, Federal Aviation Agency.

Methodological Problems and Developments

Research Design Problems

From the point of view of research methodology, the most serious weaknesses apparent in the operational test literature reviewed center about the criterion problem. The criterion problem encompasses the formulation of criterion concepts, the translation of concepts into recordable events, the instrumentation of data-gathering devices to record the test data, and finally the plan for analysis and interpretation of the recorded data. Unless this series of steps, from formulation of the test concept to conclusions about marking and lighting systems based on the test implementation, is logically developed and controlled, information is lost in the testing and results are ambiguous.

Two basic approaches to the criterion problem are noted in the flight test literature, each presenting its own peculiar methodological problems. The two approaches are defined primarily by the class of measures used - pilot opinion and pilot-aircraft system performance.

Pilot Opinion - A majority of the flight-test studies reviewed relied primarily, if not exclusively, upon pilot opinion as the basis for conclusions about the comparative effectiveness of marking and lighting systems. Questionnaires and pilot interviews were the principal data-gathering instruments and resulting data were typically statistically unevaluated tabulations or relative frequencies of responses. Such data can be evaluated by statistical means using established criteria for determining the significance of differences found in the percentages of pilots who preferred one system over another. Most of the flight-test studies did not conduct statistical evaluations of the data and therefore questions of the degree of confidence which can be placed

in conclusions drawn from the data were not resolved. The problem of whether or not differences in pilot expressions of preference are more than a chance or random difference becomes more acute as the number of pilots is small. Percentage differences must be considerably larger to satisfy a statistical criterion of significance as fewer pilot opinions are sampled. Among the studies reviewed, samples on the order of 4, 12, and 15 pilots were used as a basis for conclusions as to the relative effectiveness of marking and lighting systems. The likelihood of chance results is reduced as the sample size is increased, but even those flight-test studies which used reasonably large samples of pilots typically did not report statistical evaluations of the significance of differences observed in pilot opinions. Statistical sophistication in the data analysis, however, does not insure the validity of the test and cannot compensate for weaknesses in questionnaire construction. Questionnaire items should be derived from the specific evaluative purposes of the test. Each question and cluster of questions must provide information which can be used to evaluate each guidance category which the visual aid or pattern is designed to provide. Further, careful attention must be given to the selection of questionnaire items and the wording of the items included in the evaluation form. Care must be taken to insure that items are selected to tap the effectiveness with which specific guidance categories are provided by the visual aid. It is equally as important to insure that items are not included which reflect irrelevant or minor guidance properties of the aid, or which direct questions into specific weakness of one design and known strengths of another.

A further problem associated particularly with opinion data is that of pilot bias. Once a pilot has flown a marking and lighting system a sufficient number of times to have learned it and become comfortable using it, he is likely to favor it over any new design. This

tends to be so, within limits, even though the innovation may be a superior design. The problem of pilot experience bias is particularly notable in two of the studies reviewed in the area of angle of approach indicators: British pilots preferred the British system (Morrall, 1960); Australian pilots preferred the Australian system (Day & Baxter, 1959) in comparative tests of the two.

The general effect of experience is further illustrated by one of the studies reviewed (McKelvey, Brown, & Ontiveros, 1961b). One experimental runway lighting pattern was judged relatively low in pilot preference although performance scores placed it higher in effectiveness than some of the more preferred systems. As the pilots gained familiarity with the experimental pattern, they tended to prefer it to a degree more in line with the performance scores.

Pilot-Aircraft System Performance - Several classes of performance measures have been used as criteria. Pilot control response to information contained in his visual field can be traced through a series of outputs to eventual changes in the location of the aircraft. (See Technical Note 2, The Nature of the Pilot's Task in HSR-RR-59/1-Mk). Essentially this sequence includes a manipulation of a control surface to bring about a rate of change in one of the three rotational axes of the aircraft; a change in velocity, or aircraft attitude; and finally a change in the aircraft's three dimensional location with respect to reference point on the earth's surface. Measures of pilot-aircraft system performance can be taken at any of the several output stages of this sequence and used as criteria for evaluating marking or lighting patterns. In the typical flight test study, measures at the terminal stage of the series have been recorded and used as criteria. These measures have included deviations from ideal path in altitude and heading-line-of-flight, altitude at threshold,

dispersion of touchdown points, and vertical speed at touchdown. For the most part, these kinds of measures have failed to discriminate among the alternative lighting designs tested. Two main factors, singly or in combination, may account for this general result. First, the systems tested may not differ to any meaningful degree in the dimensions of effectiveness for which they are being tested. The designs tested may encode the necessary information in different ways but in essentially equally effective ways. The designs can be said to lie within a zone of indifference, i. e., the differential features of the two designs are not of consequence in terms of the degree to which they provide cues necessary for landing. Second, measures of aircraft performance do not necessarily reflect level of pilot input or work. By working harder, pilots may bring about equivalent aircraft performance with two lighting designs which differ substantially on the tested dimension of effectiveness.

Potential solutions to these problems in flight tests may be found in refinement of measurements, in narrowing tolerance limits of criterion flight profiles, and in development of measures of pilot effort to compare with measures of performance. Lighting designs proposed for approach and runway systems tend to be a complex of many lights and because of this, are likely to approach an indifference zone in terms of the information they contain. Overall differences among them are likely to be small or confined to one of many guidance categories and, therefore, difficult to detect. To insure that real differences in specific guidance categories are detected, measures should be included in the criterion system which reflect each category of guidance for which the marking and lighting design is proposed as an aid. To insure that minor differences in guidance properties which may exist among the patterns are reflected in the performance data, "tight" standards of flight performance must be established for the test pilots and deviations from the standard must be measured in refined scale units.

The specific nature of the criterion measurement problem will depend upon the purpose of the flight test. If the purpose is to investigate relationships between flight performance and variations in one or more dimensions of a lighting configuration, then the flight test is in the nature of an experiment conducted in an operational setting. The operational environment, in a sense, becomes a laboratory for experimentally examining the effects of variations in lighting arrangements upon one or more aspects of flight performance. In this case, relatively rigorous standards of control and measurement must be met in order to minimize the effects on flight performance of variables other than those aspects of the lighting configuration which the test was designed to investigate.

This concept of a flight test tends to be inefficient since the number of variables which can effect flight performance in the operational setting are numerous and some are impossible to control and difficult to measure accurately (e.g., wind).

If, on the other hand, the purpose of the flight test is to determine the operational suitability of a lighting design, much less stringent control and measurement standards need to be imposed. In this case, the lighting design has been developed through other means of analysis, the design is proposed as optimal on the basis of analytic, laboratory or simulator investigation, and the flight test is now conceived as a test of its operational acceptability.

Criteria of flight performance for this concept of a flight test can be based on operationally defined standards of flight safety with respect to altitude and glide slope holding, touchdown positioning, etc.

The question of differences in pilot effort required to achieve a given level of aircraft performance, however, is not answered

by efforts to detect finer differences in aircraft performances. Some measure or measures of pilot effort or input must be developed as a base to compare with measures of aircraft performance or input. Some encouragement in this direction is found in the work of Van O'osterom (1960). He found two indices of pilot work which differentiated between approach and runway lighting systems. One was a measure of pilot control effort, total excursion of control surfaces; the second was a physiological measure, heart rate. The measure of control surface excursions may reflect pilot effort, or it may reflect more refined information in the lighting pattern which permits more precise tracking. Empirical research is needed to clarify this problem and to validate other indices of pilot work load. The same type of problem occurs in attempting to interpret the results of physiological measures. Significant differences were obtained, but whether high heart rate is associated with good or poor performance is not known. In the absence of empirical validation studies, there is only a tentative, rational basis for interpreting results: the higher heart rate indicates increased response of the autonomic nervous system which may indicate the poorer lighting system. However, considerable difficulties have been experienced with physiological measures, particularly regarding the wide range of variability they exhibit and the general inability of researchers to tie these variations down to specific situational conditions. Whether or not these problems can be solved in the context of flight-test research needs to be explored.

Laboratory and Simulator Developments

Some of the central problems associated with flight evaluations are relieved by laboratory and flight simulation research.

A flight-test program conducted under varying conditions of weather, wind, and visibility, and with operational equipment, contains more variables than can be reasonably measured or controlled. Variations in these environmental aspects of the flight situation may contribute more to differences in the criterion measures than will the experimental marking and lighting systems. Laboratory simulation of a flight test can exclude these variations at early stages of evaluation to increase the likelihood that differences in criteria reflect differences among the test designs. Furthermore, the problems associated with small sample research are less expensively solved in the laboratory than in flight tests. Simulated approaches can be "flown" repeatedly with experimental lighting patterns in much less time and equipment expense.

These advantages are reflected in a program of flight simulation research recently initiated at NAFEC. Three studies have been reported from this facility (McKelvey, Brown, & Ontiveros, 1961a; McKelvey, Brown, & Ontiveros, 1961b; McKelvey and Ontiveros 1961). In each of these studies, a third approach to the criterion problem is apparent. Criterion concepts are derived from the nature of the pilot's control tasks in the flight phase for which the experimental lighting design is proposed as an aid. The function of runway landing zone patterns is to provide guidance for control of pitch, roll, heading-line-of-flight, rate of descent, flare-out, and touchdown. The pilot's task is to use the information contained in the lighting pattern as a basis for effective control of these flight parameters through proper timing and manipulation of the aircraft controls. Based on this rationale, criterion measures are devised which reflect timing and appropriateness of pilot control responses to the visual pattern presented. This approach to the criterion problem has been applied with reasonable success; criterion data both discriminate differences among lighting patterns and indicate

the direction along the criterion measure which defines favorable performance. As yet, no field validation of the simulator findings has been reported and considerable effort at NAFEC is anticipated to develop simulator test procedures and criterion measures which correlate significantly with flight-test results. The work of Gates and McKelvey to flight test distance-coded runway landing zone patterns is an encouraging beginning. Eventually, a hierarchy of test environments for efficient and incisive evaluation of marking and lighting designs will be established at NAFEC. New design ideas, experimental patterns of lights, or special visual aids can be tried out at analytic, laboratory, or simulator levels of evaluation in order to screen out inadequate proposals by test means less expensive and less dangerous than flight tests. Through a series of continuous refinements, initial design ideas can be evaluated, modified, evaluated again at simulator test levels so that expensive field tests need eventually be conducted only to verify in an operational setting conclusions reached in simulator experimentation.

Human Factors Research

The present summary of human factors information relevant to airport marking and lighting problems is restricted to results of studies published since January 1959. It is not intended to serve as a review in depth of the content categories included. Furthermore, it is recognized that human factor studies can be represented on a relevancy continuum with respect to the applicability of results to the practical problems of airport marking and lighting design. Information provided by these studies is in only a few cases directly relevant to the visual/perceptual problems of a pilot conducting a landing. Fortunately, there are a few studies which bridge the gap between the laboratory and the field conditions of concern. Studies of this type yield information of more direct value in solving applied problems since they are planned to represent the specific field conditions in which design decisions must be made. Since the human factors literature was reviewed only for recent developments, the emphasis of the following summaries is more upon the significance of human factors areas to the operational problems of landing an aircraft upon a lighted airport than upon the study findings. Relevant human factors areas should be reviewed in depth with respect to specific marking and lighting design problems. This summary only serves to highlight relevant topics.

Pattern Recognition

Perhaps the first crucial visual/perceptual task of the pilot upon transition from instrument to contact flight in IFR landings is to quickly orient himself with respect to the duty runway. In VFR flight, an early and often difficult visual task is to discern the airport from the surrounding pattern of city lights. Both of these tasks involve pattern recognition and the human factors research literature in this area should provide some guidance for lighting designers. In the case of VFR flight, the landing areas of the airport or heliport should be an easily recognized shape, i. e., one whose shape is associated with low visual recognition thresholds regardless of the observers orientation. In the case of IFR flight, the shape of the approach and runway configuration is the design element which must be easily recognized.

The results of two recent research studies provide useful information relevant to these problems. Gaito (1959) studied recognition thresholds for a variety of geometric forms and found that straight line forms were most readily identified and that more complex patterns are frequently mistaken for straight line forms. In a study of reaction time to visual patterns, Hodge (1959) found reaction time to increase as irrelevant information is presented with the principal stimulus material. Results of human factors studies such as these tend to provide clues to understanding results of operational tests such as those conducted by Strong (1959). In this flight test, pilots reported that bars of lights outboard of the approach centerline were distracting. These results suggest that patterns should be as simple and uncomplicated as possible, while still providing the essential information to the pilot.

Luminance and Visual Acuity

A fundamental problem in the design of airport or heliport lighting systems is to insure that lights are sufficiently intense for the pilot to see in low visibility while at the same time guard against serious degradation of the pilot's dark adaptation level. This problem is particularly acute in the design of approach and runway lighting systems. The approach lights tend to be of very high intensity so that the pilot can find them quickly upon break-out from ceiling. Exposure to this high intensity light level, however, makes more difficult the pilot's problems in judging height above runway and rate of closure with the runway. These judgments are critical to the timing of flare-out and touchdown.

Human factors studies in this category present a consistent conclusion: visual acuity is a function of the viewed situation and the immediate history of the viewer's visual stimulation. Visual acuity thresholds will be affected by the contrast of the object of focus with its surround and by the location of the stimulus object in the viewer's visual field. Important "historical" factors are the intensities or luminances to which the viewer has been previously exposed, the duration of that exposure and the length of time elapsed between the previous and present stimulus complex. Visual acuity will be adversely affected as the previous stimulation was of high intensity, long duration, and the interval between previous and present view is short. Recovery time for dark adaptation following intense stimulation has been found to be on the order of 60 seconds (Boardman, 1961). This is a very long time interval considering the few seconds (approximately 12) from break-out to touchdown for a commercial jet and a 300-foot ceiling.

A study by Wolf and Zigler (1959) is of particular interest to the problems of designing runway landing zone patterns. If the area of the retina stimulated by a glare source light is different from the retinal area later stimulated by a target source, visual acuity is less seriously impaired than if the same retinal area was stimulated by both sources. This finding should suggest a basis for predicting the superiority of wide gauge runway patterns over narrow gauge or centerline patterns. In the latter two designs, the central portion of the retina is exposed to intense stimulation from the approach lights. Immediately thereafter, approaching the point of touchdown, the central part of the retina is stimulated by a row or two rows of lights whose intensity is far below that of the approach lights. This condition would tend to reduce the effectiveness of the centerline or narrow gauge lights.

Dynamic Visual Acuity and Motion Perception

The ability to perceive moving objects and rates of movement of the objects may be a critical factor in the judgment of rate of closure with the surface. J. J. Gibson presented in the May 1959 HSR report a formulation of the visual cues necessary to land an aircraft. In essence, this formulation states that the visual field of a pilot on glide slope exhibits radial expansion such that the center of the expansion pattern defines the point at which the aircraft will intercept the runway and the relative velocities of the "streamers" emanating from this center spot contain cues to rate of closure with the surface. This theory has relevance to the pilot's problems in final approach and flare-out. If the theory is valid, the pilot may be able to use expansion pattern to check for deviations in pitch and heading-line-of-flight. If the center of the expansion patterns remains fixed longitudinally, the pilot obtains confirmation that the aircraft is on a constant glide slope and no pitch corrections are required. If the center of the expansion pattern remains fixed laterally, the pilot obtains confirmation of a correct heading-line-of-flight and no aircraft flight corrections are needed. There were no empirical studies during 1959-1961 which support or deny this theory.

Empirical studies in this problem area have been directed to the establishment of visual thresholds for motion perception and are a long series of steps removed from providing operationally meaningful information for design of runway launching zone patterns. Absolute threshold for motion is on the order of 1 to 2 minutes of arc per second. Visual acuity thresholds for moving objects increase with increased speed of the object and with increasingly peripheral vision (Crawford, 1960). Caution must be exercised in generalizing these empirical results since the laboratory tasks involve judgments of stimuli moving in a vertical or horizontal plane at a constant distance from the observer.

The operational situation in landing an aircraft, on the other hand, involves motion in the direction of the stimulus field and visual cues to motion may be contained in radial expansion of the visual field.

Size-Distance Judgments

Judgment of distance in both range and altitude is a constant task requirement of the pilot on final approach. One of the potential cues to distance estimation is the perceived size of an object or an interval between lights relative to its known size. Pilots report using the interval between runway lights, for example, as a cue to altitude and the rate at which this interval changes as a cue to rate of descent. Since this interval is relatively standard (200 feet) from airport to airport, it is a reliable cue.

Previous studies of visual acuity would indicate that, under ideal laboratory conditions, an object must have a visual angle subtense of 1-5 minutes. These results have generally been based on work with Snellen charts and Landolt rings. Steedman and Baker (1960) studied target discernability in a display context similar to a radar return display. Both target search time and error remained invariant, under a range of target resolutions, until the visual angle subtense of the target fell below 12 minutes. Below 12 minutes, performance deteriorated. Miller and Ludvigh (1959) reported detection threshold of 20 minutes of arc for objects in homogeneous or partially structured stimulus fields. The airport designer should use such figures as minimums since the viewing conditions of the laboratory task are not representative of operational conditions.

Response Latency to Visual Stimuli

Pilot reaction time latency to a visual stimulus situation is one of three time factors (delays) involved in the low visibility landing problem. As the pilot breaks out of an overcast and the approach lights become visible, the first time delay occurs as the pilot makes a control manipulation in response to the visual stimulus; a second time delay occurs as the aircraft control surface deflections rotate the aircraft about the controlled axis; a third time delay occurs as the rotation brings about a positional displacement of the aircraft. The principal contributor to pilot response latency is the ease or difficulty with which the pattern can be interpreted. If the pattern contains ambiguous or conflicting information with respect to the guidance parameters it is to provide, the pilot is confronted with a difficult decision problem and response time will be significantly delayed. Assuming the lighting pattern does not present conflicting or distracting information, pilot reaction time will be on the order of milliseconds. Studies of response to single light parameters such as luminance or duration demonstrate the insignificance of these parameters to the operational problem of low visibility landing. A study by Raab, Fehrer, and Hershenson (1961) varied luminance as follows: .30, 30, and 3,000-foot lamberts. Reaction time to the 3,000-foot lambert light averaged 12 milliseconds faster than to the 30-foot lambert and 39 milliseconds faster than to the .30-foot lambert lights. Stimulus duration of a light flash was varied in this study from 10 to 500 milliseconds. Reaction times to the shortest duration flash (10 milliseconds) was, on the average, 2 milliseconds longer than to the 500-millisecond flash. The range of differences in reaction times to the luminances and flash durations studied clearly are not significant to the evaluation of alternative lighting designs.

**PART II: ANNOTATED BIBLIOGRAPHY OF OPERATIONAL
TESTS AND HUMAN FACTORS RESEARCH, 1959-1961**

Operational Tests and Design Developments

Beacons

R1 .ENCE

National Bureau of Standards, Visual Landing Aids Field Laboratory, Photometry and Colorimetry Section, Optics and Metrology Division. An approach-beacon system. Washington, D. C.: Author, February 1959. (National Bureau of Standards Report No. 5902)

PURPOSE

This report contains a description of tests conducted with a low cost approach-beacon system. The system is designed to provide early localization of the airfield and visual guidance during circling and approach to the runway.

SUMMARY

Procedure The approach-beacon system consists of two rotating beacons: one placed at 1,000 feet and another at 2,000 feet from the threshold on the extended runway centerline. Beacons used in tests rotated at 12 rpm, provided a flash duration of .5 seconds, a flash frequency of 72 per minute, a peak effective intensity of about 20,000 candles, and an effective intensity of about 12,000 candles at ± 5 degrees of the peak. The system was installed and tested at Arcata Airfield, California.

Flight tests were performed by an unspecified number of commercial airline pilots, business aircraft pilots, and private pilots during normal operation of the airport. Comments of the pilots were recorded during approach or upon completing landing.

Results Spacing of the beacons was adequate for alignment guidance. An additional beacon at 3,000 feet may be necessary for operations in visibilities of 1 mile or less.

Guidance is provided by the beacons on the downwind leg and in directions where runway lights are not adequate.

Beacons provided identification information at ranges greater than 8 miles in daytime and 12 miles at night under VFR conditions.

Although some pilots had no previous knowledge of the system, no confusion resulted even when no familiarization run was made.

When beacons were operated on high intensity, pilots reported annoying glare under some nighttime conditions. There were no reports of bothersome glare when the beacons were operated on low intensity even on clear, dark nights. The high intensity was satisfactory for overcast daytime and twilight conditions. For clear nighttime conditions, several pilots suggested using the beacons at high intensity for identification, off-axis guidance, and early alignment and then switching to low intensity after the runway lights have been sighted.

REMARKS

Appendices to the report contain a list of equipment needed, an installation guide, and maintenance and operating instructions for the approach-beacon system.

Angle of Approach Indicators

REFERENCE

Baxter, J. R., Cumming, R. W., Day, R. H., and Lane, J. C. A comparison of three visual glide path systems. Melbourne: Department of Supply, Australian Defense Scientific Service, Aeronautical Research Laboratories, October 1960. (Human Engineering Note 8)

PURPOSE

An experiment was conducted to compare three systems of visual glide path guidance: the Visual Glide Path Indicator (VGPI), the Precision Visual Glidepath (PVG), and the TEE Visual Glidepath (TVG). The criterion measures used to evaluate them were: (1) deviations from an ideal approach measured by a recording theodolite and (2) subjective verbal reports of pilots.

SUMMARY

Procedures Fifteen pilots (from the United States, Australia, and England), eleven of whom had some previous experience on the DC-3, were used as test subjects. These eleven pilots were airline captains. The remaining four were test pilots with some previous experience on the C-47.

Each pilot completed a daytime detail consisting of a demonstration approach, a practice approach, and a test approach on each system. This was followed by a night detail consisting of a practice and a test approach on each system. The test approaches were tracked by recording theodolite from 6 nautical miles to threshold. All approaches were made with gear down and no flap at an airspeed of between 105 and 115 knots. Pilots were asked to continue the approach to the threshold before commencing the overshoot.

Throughout the tests, wind and visibility conditions varied considerably, but no recorded approaches were made in conditions such that the runway or runway lights were not detectable from 6 nautical miles.

The authors interviewed the pilots following both day and night details. The interview took the form of a discussion on the need for visual guidance and comments on the three systems and adequacy of the experiment. Considering all relevant factors, each pilot was then asked to make a specific choice between the systems, taken two at a time.

Results Plots of approach profiles show that approaches made with TVG appear more accurate in the last 3 miles than those made with the PVG or the VGPI. There is little difference between these latter two systems. Subjective data indicate that when experiencing the full TVG system, pilots prefer it to the VGPI or the PVG.

Improvement in glide path holding as distance from threshold decreases is apparent for all three systems.

All 15 pilots stated a need for visual glide path guidance.

REMARKS

Lists of favorable and unfavorable comments by pilots on various aspects of the three systems are included in the report. The best and the least liked features of each system are also included.

Patterns illustrating the TEE system plan view, and the TEE system pilot's view are presented in Figures 2 and 3 found on pages I-8 and I-9.

REFERENCE

Cumming, R. W., Lane, J. C., & Baxter, J. R. Installation notes on the precision visual glidepath (PVG). Melbourne: Department of Supply, Australian Defense Scientific Service, Aeronautical Research Laboratories, July 1959. (Human Engineering Note 3)

PURPOSE

This paper was written to describe the design features of the PVG and to show how it might be installed in "difficult" locations.

SUMMARY

The PVG is a visual approach aid for use in moderate to good visibility. It is of most value when natural vision is limited.

This report contains information on the following aspects of PVG use:

Information offered by the PVG - alignment of white and amber bars indicates that the predetermined glide path is being followed. Misalignment indicates the magnitude and direction of displacement from the glide path.

Height at threshold - the PVG guides the pilot so that his eyes pass over the threshold at a height of 45 feet, thereby allowing the wheels of the aircraft to pass threshold at a safe height.

Fly-up warning light - high intensity red flashing lights are seen on each side of the runway on a dangerously low approach.

Detailed description of the PVG is given.

Variations from the standard layout suggestions are proposed on PVG installation under the following unusual conditions:

Approach plane other than 1 in 20.

Longitudinal runway gradient.

Transverse airfield gradient.

Interfering runway or taxiway pattern.

Runways more than 200 feet in width.

REFERENCE

Day, R. H., & Baxter, J. R. A comparison of two types of visual approach aids. Melbourne: Department of Supply, Australian Defence Scientific Service, Aeronautical Research Laboratories, January 1959. (Human Engineering Note 4)

PURPOSE

This experiment was designed to compare two types of glide path approach aids, the Angle of Approach Indicator (AAI) and the Precision Visual Glidepath (PVG), with respect to their relative merits in presenting glide slope information to pilots on final approach.

The principle of approach guidance utilized by the AAI is the visual presentation of specific color changes in a series of lights on the ground. Departures from the correct approach corridor are indicated by color changes. The PVG offers approach guidance by means of the alignment of bars of light. At a given range, the departure from the standard glide path is indicated by the degree of misalignment of the bars.

SUMMARY

Procedures Twelve Australian airline pilots of three different Australian airlines served as test subjects. Their experience ranged from 2,000 to 20,000 hours. All pilots were flight captains and had previous experience with the DC-3, the type of aircraft used in this test. Time elapsed since pilots had flown DC-3's ranged from days to 6 1/2 years.

The pilots were informed of the general purpose of the experiment and of the procedure to be employed. The names of the two aids were coded so that the pilots had no indication of their origin.

Each pilot made three successive approaches on each aid and rested in the cabin between his two sets of three approaches. A safety pilot from the Department of Civil Aviation (DCA) accompanied all the flights and sat in the right-hand seat. The approaches were arranged in the following manner. First, there was a familiarization approach from about 6 nautical miles. At this time, the safety pilot explained the interpretation of the light signals. During the first approach, the airline pilot deliberately flew above and below the glide path in order to experience the changes in signals. The second approach was a circuit approach from a base leg at 4 nautical miles, 1,000 feet above runway level. The third approach was a long straight-in-approach from 7 nautical miles, 1,500 feet above runway level.

The approach path was recorded by means of theodolite tracking. After the tests, the pilots were asked to respond to questionnaires. The questionnaires asked for comparisons between the two aids.

Results Height deviations from the mean glide slope, measured with the theodolite, were not statistically different. For both approach aids, a comparison of the mean of the height deviations at long range with the mean of the deviations at short range shows a significant reduction at short range.

With regard to the questionnaire data, all pilots considered approach aid either necessary or desirable under all the night conditions mentioned, i. e., clear visibility with well-lighted foreground, clear visibility with unlighted foreground, and reduced visibility with unlighted foreground. Each pilot was asked a number of questions concerning

advantages and disadvantages of various aspects of each aid. In each question asked, the pilot stated a preference for one of the aids. Of the 157 answers recorded, 63 favored the PVG, 24 the AAI, 53 favored both equally, and 17 indicated that neither aid was useful. When the pilots were asked to express a preference for one of the aids, 9 favored the PVG and 3 the AAI.

REFERENCE

Day, R. H., Baxter, J. R., & Lane, J. C. The psycho-physical testing of an aircraft visual approach aid. Human Factors, 1961, 2 (4), 203-210.

PURPOSE

The purpose of this paper is to describe a ground-based approach aid, the Precision Visual Glidepath (PVG), and to outline a number of psychophysical tests which have been applied to it. A comparison between laboratory test results using a simulator and a field test of the actual PVG was made in order to validate the laboratory simulator.

SUMMARY

Procedure Ten pilots, experienced in PVG, and thirty-five non-pilots participated as observers in the first two experiments. The observers in the last two experiments consisted entirely of non-pilots and were shown to have at least 20/30 vision in each eye.

A laboratory simulation of the display was constructed on a 1 to 1,000 scale. This consisted of an internally illuminated box with a series of .006 arc holes drilled in its face. These holes formed PVG patterns with various misalignment presentations exposed one at a time.

The first test was to determine misalignment thresholds. Pilots were asked to indicate whether the alignments were sufficient to justify corrections up or down, and non-pilots were required to make a misalignment threshold judgment.

The second test was a validation of the laboratory simulator results. The same observers who participated in the first test were used. The pilots were asked to make the same judgments as previously, but the non-pilots were required to make a two-choice judgment, "white high" or "white low".

The third test was to determine whether the inclusion of rows of runway lights in the center of the display would affect judgments of misalignments. Simulated runway lights were added to the display, and different misalignments were randomly presented.

The fourth test was to determine the effects of an aircraft windscreen and atmospheric alteration of the display. This was done by constructing a small cabin with an aircraft windscreen and by having water blown onto the windscreen. Twelve pilots were presented several different misalignments in random order and were asked to judge the adequacy of the signal they received.

Results At a range of about 7 nautical miles in misty weather conditions, 95 percent of pilot judgments was to take "fly-up" corrective action during a PVG approach when the misalignment was 54 seconds of arc. Under the same conditions, a misalignment of 39 seconds was detected by non-pilots.

The 1 to 1,000 scale simulator, matched in intensity with the full scale display, was a reasonably valid representation of the full scale display.

In both the field and laboratory test, pilots and non-pilots both consistently judged the white and amber bars to be in line when, in fact, the white bar was from 1 to 4 seconds of arc below the amber bar.

There was no significant effect on misalignment judgments when a runway light pattern was included.

A wet windscreen, a windscreen wiper, and a 50 percent reduction from normal light intensity deteriorated the sensitivity of judgments of the non-pilot observers. However, only 2 out of the 12 observers expressed the opinion that the attenuated display was "unusable".

REFERENCE

Griffith, R. S. Installation and testing of visual glide path indicators. Atlantic City: National Aviation Facilities Experimental Center, June 1960. (Final Report, Task Assignment No. D-2-8045)

PURPOSE

Five different types of visual glide path indicators were evaluated and compared by means of flight tests. The study was initiated in order to select a system as the national standard.

SUMMARY

Procedure The testing was divided into two phases. The first 6 weeks were spent evaluating all five systems (Westinghouse Tri-Color, Navy Mirror, USAF Interim Mirror, Australian Cumming-Lane, and British RAE). The second 6 weeks were spent in selecting one system as the national standard.

In order to secure test pilots, letters were sent to military services and other aviation organizations soliciting pilot volunteers. This procedure provided more than 100 subjects. The pilots ranged in experience from a private pilot with 500 hours to an ex-airline captain with more than 20,000 hours. There were also participants from several foreign countries. The aircraft used in the testing ranged from a Piper Tri-Pacer to a Boeing 707. Flights were conducted in both daylight and night conditions, usually in weather conditions above a 1,500-foot ceiling and 5 miles visibility. In the briefings given to the pilots, the systems were given code names. Unrecorded

familiarization runs were made by all subjects for each system. Objective data were obtained by means of phototheodolite equipment. Subjective data were obtained by means of a questionnaire in which the pilots expressed opinions on various aspects of the systems.

Measurements were made to investigate the effect of visual aids on touchdown dispersion and the time required for a pilot to correct his glide path after being deliberately misplaced while under a hood. A highly qualified F9F-8T pilot was used for this purpose.

Results Of the more than 100 subjects who participated in the tests, questionnaires were returned by 62 and abbreviated comments by 17 others.

The decision was made to concentrate on the RAE and Cumming-Lane systems. This decision was based upon the analyses of almost 400 runs and on preferences by the participating pilots. Only the results of test flights and questionnaires concerning these two systems were, therefore, presented by the authors.

A measure was made of the distance flown after the pilot first reported lights in sight and before he reported that he was able to determine his position with respect to the glide path. For the Cumming-Lane system, out of 29 runs, only one pilot reported guidance immediately upon seeing the system. For the RAE system, out of 22 runs, four pilots reported guidance immediately upon seeing the lights of the system. This indicated that the RAE system provided a quicker indication of position.

The objective data revealed no significant differences in aircraft trajectory between the two systems but that the RAE system gave better guidance close to touchdown.

Recordings of touchdown dispersion were inconclusive so that no further work in this direction was pursued.

With regard to the subjective data, 34 subjects indicated that Visual Glide Path Indicators were unnecessary in clear daylight conditions; 24 indicated that they were desirable; and 2 felt that they were necessary. The largest number of responses (47) felt that this type of guidance was necessary under night and reduced visibility conditions. The same number felt that guidance at night, with clear conditions and a well-lighted foreground, was desirable.

Thirty subjects thought that the RAE system completely satisfied guidance needs, and 28 subjects thought that the RAE only partially satisfied this need. The Cumming - Lane system was considered completely adequate by 15 subjects and partially adequate by 14 subjects.

Of 14 various aspects of the systems, the RAE was judged to be better in 11; the Cumming - Lane system better in 2.

The initial cost of the complete RAE system is higher than for the Cumming - Lane system, but maintenance is less of a problem than in the Cumming - Lane.

The authors recommended that the RAE Visual Glide Path Indicator, consisting of 12 RAE units, be adopted as the United States national standard.

REFERENCE

Ministry of Aviation. Criteria for installing two-colour visual glide path indicators (Second edition). London, W. C. 2: Author, February 1960. (DAT. Paper No. 11)

PURPOSE

This paper gives the specifications for installing the two-color VGPI under both standard and non-standard conditions.

SUMMARY

Requirements for VGPI installation are specified for approach angles from 2 1/2 to 4 1/2 degrees. The complete system comprises two pairs of wing bars of light running transversely to the runway. In full installation, each half bar consists of three units, each containing three light sources.

In some instances, a full system may not be required; only the left-hand bars may be used or the half bars, composed of less than three units, may be used on each side of the runway. The following setting requirements, considering both standard and unusual conditions, are specified:

Clearance from runways and taxiways.

Operational requirements.

Maximum tolerances.

Elevation settings.

Approach clearance requirements.

REFERENCE

Morrall, J. C. A flight assessment of two methods of indicating a visual glide path - the R. A. E. visual glide path indicator, and the A. R. L. double bar ground aid. London, W. C. 2: Ministry of Aviation, Royal Aircraft Establishment, April 1960. (Technical Note No. BL. 48)

PURPOSE

This study was to compare two approach angle indicators (VGPI and A. R. L. Double Bar) in terms of assistance, ease of use, and ease of interpretation of the system's indications, roll, and azimuth guidance.

SUMMARY

Procedures Four British test pilots from Blind Landing Experimental Unit (BLEU), experienced in the assessment of a wide variety of approach and landing aids, served as subjects for the tests. The tests extended over a 12-month period in order to sample a wide variety of weather conditions. Four aircraft were used: Devon, Varsity, Meteor, and Javelin. About 250 approaches were made on each indicator, approximately 60 percent by day and 40 percent by night.

The Varsity aircraft was equipped to record indicated air speed, altitude, control surface movements, and ILS glide path and localizer signals. The aircraft was also photographed from the ground to establish the flight path. In addition to the quantitative data, qualitative assessments based upon pilot's flight reports were compiled.

Results In fair weather, by day and night, both indicators provide glide path guidance which will reduce appreciably the risk of undershoot accidents. At longer ranges the VGPI is more sensitive, but for a small proportion of the approaches there is difficulty in distinguishing between the colors. This conclusion was based upon glide path holding measurements. However, since these quantitative data did not yield any significant difference between the two systems, it was abandoned as a criterion measure, and study conclusions were based upon the qualitative data.

In reduced visibility and/or low cloud base, the VGPI provides much better guidance because it can be used to runway threshold. The bars of the A. R. L. Double Bar system appear to "fly apart" at altitudes below about 150 feet, and the aid is no longer of use. Measurements taken when the pilots reported "fly apart" provided this information.

The VGPI will provide the greater assistance for establishing good glide path stability for future aircraft. It will also be of value during low visibility automatic landings since even under poor visibility conditions, there was little difficulty encountered in making the color discriminations.

REFERENCE

Olson, H. A. Report of service test. Visual glide slope landing aid system. ("VIGSLA"). Hamilton Air Force Base, Calif.: Headquarters Western Air Defense Force, Air Defense Command, United States Air Force, September 30, 1959.

PURPOSE

This study was conducted to evaluate VIGSLA angle of approach indicator and to compare it with other existing systems or experimental systems. The present report includes only the operational test of VIGSLA and, in order to make comparisons, refers to previously conducted tests of the other glide path systems.

SUMMARY

Procedure VIGSLA was designed to simulate perceptually the ILS cockpit instrument. The visual pattern of both VIGSLA and ILS instrument coincide, and deviations from the optimal glide path give corresponding visual indications. Therefore, few problems of interpretation are anticipated in switching from ILS to visual approach.

The first component of VIGSLA is a pair of frangible panels, one pair on each side of the runway. The inboard edge of the panels is 75 feet out from the runway edge. These panels are lined up with a reference line painted on the runway. The second component of the VIGSLA system is the lateral runway reference stripe painted on the surface of the runway. The panels move up in relation to the stripe when the aircraft goes below glide path and vice versa.

A VIGSLA system was installed at Hamilton Air Force Base, California and at McChord Air Force Base, Washington. The Project Officer conducted briefings to ADC pilots at Hamilton and to the two tactical squadrons at McChord. An instruction guide to the use of VIGSLA and a questionnaire were prepared and sent to commanders of Air Force bases using McChord and Hamilton. In the questionnaire forms, the recommended flight technique was explained; the similarity of presentation to the ILS system was pointed out; and clues and interpretations of the VIGSLA system were described. Conclusions about the adequacy of VIGSLA were drawn based upon the responses of the pilots to questionnaires.

Results Seven criteria for evaluating an angle of approach, extra cockpit visual aid were defined, and several types of visual aids were reviewed in terms of the criteria. Criteria were simplicity, accuracy, economy, visibility, flexibility, durability and ease of interpretation. Five visual aids were reviewed: Lockheed POMOLA Spot Landing Aid, U. S. Navy Mirror Landing Aid, U. S. Navy POMOLA Richards-Gebaur Air Force Base "Meatball", and Royal Air Force Tri-Color Glide Slope Indicator. On the basis of rational analysis, each of these five systems was concluded to be inferior to VIGSLA for VFR conditions.

Figure 4, page I-11, is an illustration of this system.

REFERENCE

U. S. Naval Air Test Center, Flight Test Division.
"Crossed lights" optical landing system. Evaluation of
report no. 1. Patuxent River, Md.: Author, March 1960.
(Project No. PTR SI-5009)

PURPOSE

This study was performed to evaluate the Crossed-Lights Optical Landing System (CLOLS) and to compare it with the present Mirror Optical Landing System (MOLS).

SUMMARY

Procedure The CLOLS consists of a viewing device and a display of light sources. The viewing device can be either a flat transparent screen mounted in the aircraft or a curved transparent visor mounted in the pilot's helmet. Cross hatch lines are scribed on the viewing screen to form cylindrical lenses. Five light sources are mounted in the landing area: two primary, two secondary, and one target light. (See Figure 5). When viewed through the cross hatch screen, the lights appear to spread into lines which form reference cross intersections. The pilot's task is to align the target light with the apex of the cross intersection, thus maintaining correct glide angle and heading. Six pilots flew 31-day and 7-night flights, using nine different aircraft types (those currently in fleet use) under various weather and visibility conditions.

Results Qualitative evaluations of the CLOLS were made by means of debriefing questionnaires. The following results are based upon these subjective data:

Pilots reported little difficulty in lining up with the direction of approach. Heading guidance was provided by the light display even when the viewer was not used.

Glide path information was provided even at extreme vertical and horizontal deviations. Pilots experienced no difficulties in maintaining contact with the system as may be the case with MOLS. The reference cross could be monitored all the way to touchdown. Also, the glide path presentation of the CLOLS was more sensitive than that of the MOLS, thereby permitting earlier corrections to be initiated.

During night operations, the intensity of the light system had to be reduced at the sacrifice of range so as to eliminate glare. Range of the system, however, was considered acceptable.

Interference from lights within and without the cockpit had negligible effect on the pilot's monitoring of glide path display information. The contrast between primary and target lights, however, was not considered, and the system would be improved by the addition of a color filter to the target light.

The initial impression of pilots was that the viewer limited visibility because of a "dirty-windshield" effect. These objections were reduced as the pilots became familiar with the systems. Also, size of the screen can be reduced, particularly in the vertical dimension.

The helmet viewer was found unacceptable for night operation because it completely precluded the pilot's instrument reading by diffusing all the cockpit lights on the visor.

Touchdown point dispersion was comparable to or superior to that with MOLS. Throughout the course of the tests, no aircraft touched down short of the calculated touchdown point.

A plan view and a pilot's view of the CLOLS are illustrated in Figures 5 and 6, found on pages I-14 and I-15 respectively.

Approach and Runway Lighting Systems

REFERENCE

Finch, D. M., & Horonjeff, R. An evaluation of surface-mounted lights for runway guidance. Berkeley: University of California, The Institute of Transportation and Traffic Engineering, June 1960. (Final Report, Contract FAA/BRD-4)

PURPOSE

This study was undertaken to determine the efficiency of visual guidance provided by closely spaced, low-wattage lights mounted on a runway in a linear pattern.

SUMMARY

Procedure Surface-mounted lights (described fully in the Interim Report dated April 1959) were positioned near the threshold end of the San Francisco International Airport runway 28R in the following manner: two 200-foot long parallel lines of lights, 40 feet apart, and a centerline of lights extending between them and continuing down the runway after the parallel lines had stopped. Transverse bars were composed of bar lights of 5 volts and 6-inch spacing. Edge lights were 5-watt units and were spaced 5 feet apart. The centerline itself was comprised of lights of the following specifications: 300 feet, 15 watts, 2 1/2-foot spacing; 200 feet, 10 watts, 2 1/2-foot spacing; 2,000 feet, 5 watts, 5-foot spacing; and 2,400 feet, 3 watts, 10-foot spacing. All centerline lights were switched on and off together although the transverse bars could be switched separately.

A set of counters and time registers was added to the control system in order to determine how many times and for how long the system was used. The brightness settings (high, medium, and low)

were requested by the pilots directly to the control tower. No record of the visibility conditions at the time of the request is available.

Flight questionnaires were distributed to the airlines, requesting that they be filled out by a few pilots using the lighting system preferably under conditions of poor visibility. Control tower personnel were asked to obtain comments of the pilots during poor visibility conditions.

Results Low brightness settings were requested only 4 times in a given 25-hour period; medium brightness settings, 34 times in a 25-hour period; and high brightness settings, 33 times in a 17-hour period. The overwhelming number of medium and high brightness requests indicated that the low brightness setting was not satisfactory for conditions of restricted visibility. However, in the winter during which the data were collected (1959-60), there were very few minimum weather conditions encountered. Further observations under minimum visibility conditions are required before any conclusions can be drawn.

One pilot who landed in near minimum visibility requested high brightness and later commented that he could not have made the landing without the centerline system.

In the questionnaire, some pilots noted the lack of visual guidance in correcting the attitude of the aircraft. This was explained by the fact that a single centerline will not give complete information on bank, pitch, height, or distance-to-go on runway.

Most of the pilots did not complain about the roughness of the button lights although they stated that they could feel them.

The authors conclude that a single centerline, in conjunction with runway edge lights, is adequate under normal conditions to supply

most of the visual information needed. When weather is bad, however, additional linear patterns and surface texture information are desirable.

Figure 13, page I-36 of this report is an illustration of this pattern.

REFERENCE

Gas runway lights get attention in year of rigorous testing for use on small runways. Gas, 1961, 37, 70.

PURPOSE

This article contains a summary of current usages and tests of gas runway lights.

SUMMARY

The chief application of gas lights thus far has been limited to small airfields servicing non-commercial, private traffic. A typical installation (Benton, Arkansas) consists of 52 Arkla "Gaslites", which illuminate the 3,100-foot runway.

The unit is mounted on a 9-inch metal cone anchored to the ground with 2-inch steel pipe, 1 foot above ground with the top of the unit 27 inches above ground.

The advantages of the Benton system are its low installation cost and maintenance costs. The Arkansas-Louisiana Gas Company estimates that the system can be operated at less than \$1.00 per day while the initial cost of each unit is only \$20.00 with a life expectancy of 20 years.

The emitted soft glow of the gas light may be a desirable contrast to the glare with which pilots usually must contend. The lights are not an obstruction hazard in that they will give on impact.

REFERENCE

Louisiana airport uses gas to light 3,600-ft. runway.
Gas Age, 1959, 124 (3), 17.

PURPOSE

This is a description of the third gas light installation of runway illumination in U. S. A. at Minden Airport, Minden, Louisiana.

SUMMARY

Fifty gas lights were installed along a 3,600-ft. runway. Spacing between units was 184 feet to the north and 176 feet to the south, using clear glass lenses. Six lights at each end of the runway had green filters to define the threshold. Taxi strip had blue lenses.

The Arkla Sentry light for lighting the runway was mounted on top of a metal cone to allow the light to give upon impact. The metal cones were painted the international yellow (No. 1310), and the top of the lights were porcelainized in a yellow color to match.

REFERENCE

Jewell, M. E. Runway narrow gauge and centerline lighting systems. Washington, D. C.: Department of the Air Force, July 1961. (Memorandum)

PURPOSE

This report describes in mechanical and electrical engineering detail the criteria for the installation of narrow gauge and centerline lighting systems to be installed at Air Force runways.

SUMMARY

Drawings and engineering specifications are attached to the memorandum that describes the criteria to be met for Air Force installation of narrow gauge and centerline lighting systems. The engineering details of the type of concrete to be used, thickness of concrete, depth for light sump, electrical wiring specifications, etc. are not included in this annotation.

Narrow Gauge Lighting - A narrow gauge lighting system consists of two longitudinal rows of light bars, arranged symmetrically about the runway centerline. The first light bar in each row is located 200 feet \pm 12-1/2 feet from the runway approach threshold. The subsequent bars in each row are equally spaced on 200-foot centers for a distance of 3,000 feet. There are a total of 16 light bars in each row. The light bars on each row are located in a transverse position on the runway so that the innermost light of each bar is 30 feet from the runway centerline. Each light bar will consist of three open grid lights or five inset lights equally spaced to form a bar 9 feet long, measured

between the centers of the outermost fixture in a bar. Details of the Open Grid, Class C-3, Light, Specification MIL-L-26202 are shown.

Centerline Lighting - The centerline lighting system consists of a longitudinal row of inset lights on or along the geometric centerline of the runway. The center-to-center spacing of the inset lights shall be a minimum of 10 feet and a maximum of 12.5 feet. It is desirable that the inset lights be on the geometric centerline of the runway; however, on most runways there is a joint in rigid pavement somewhere along the length of the runway. When this condition exists, it is necessary to offset the inset lights from the geometric centerline of the runway. The offset distance shall be a minimum of 12 inches and a maximum of 18 inches and the runway centerline marking will be moved to coincide with the inset lights.

The first inset light shall be 25 feet \pm 5 feet from the last bar of narrow gauge lights. It is desirable that the spacing of the inset lights be consistent from beginning to end; however, individual lights may be moved longitudinally as much as 12 inches when necessary to miss joints or structural cracks in the rigid pavement. The last light in the centerline lighting system shall be within 200 feet \pm 5 feet of the runway end opposite the instrument approach threshold. The last three lights on the centerline lighting system may be omitted if they require a separate isolating transformer and secondary circuit to feed them. A circuit in the centerline lighting system contains five inset lights in series on each transformer. A four-light circuit can be used whenever absolutely necessary to meet the dimensional requirement.

REFERENCE

Lane, J. C., & Cumming, R. W. Pilot opinions and practices on the approach to landing: A questionnaire survey among Australian civil and military pilots. Melbourne: Department of Supply, Australian Defense Scientific Service, Aeronautical Research Laboratories, April 1959. (Human Engineering Report No. 1)

PURPOSE

This investigation was initiated to yield information on the visual cues used by pilots in final approach. Questionnaires were used to collect data bearing on cues involved in under/overshooting the runway.

SUMMARY

Procedure A sample of 200 airline captains, each of whom held a first class Airline Transport Pilot License, was randomly selected. Another sample of 173 licensed commercial pilots with instructor ratings was selected from the licensing records of the Department of Civil Aviation. A third sample ($N=150$) was randomly selected from among R.A.A.F. transport, jet fighter, jet bomber, and piston-engine bomber pilots.

The questionnaires were tailored to each pilot group (instructors, commercial, and military). The returned questionnaires were examined by computing percentages of responses for particular categories, and where appropriate, statistical tests were conducted. Forty-six percent of the airline pilots and civil instructors, fifty-five percent of the R.A.A.F. pilots, and sixty-seven percent of the R.A.A.F. instructors responded to the questionnaire.

Results Approximately half of the military and three-fourths of the civil instructors were conscious of using an aiming point. When an aiming point was used, most of the pilots reported that they chose a location fairly close to the runway threshold (0 to 300 feet) even though landings occur beyond these points.

One-third of all uncomfortable incidents were reported to have occurred on dark nights, having no moon or unlighted runways.

Significant visual cues reported as used in the final approach were:

- The consistency of the length of the runway.
- The constant position of the aiming point relative to the windshield or the nose of the aircraft.
- "The distance between lights" for night approaches.
- The importance of change in appearance of the runway or other fixed referent. (About one-half of the instructors and pilots could visualize or sketch the changes in the perspective appearance of the runway during final approach.)
- The desirability of referring final approach descriptions to distance and angle rather than to distance and light.

REFERENCE

Loch, C. H. Design and performance of an inset runway light.
Illum. Engng., 1960, 55 (9), 480. (Abstract of Illuminating
Engineering Society Conference Paper No. 9)

PURPOSE

This article contains a discussion of problems involved in installing signal lights in runways.

SUMMARY

The placement of signal lights in pavements to provide narrow gauge, centerline, and taxi exit lighting configuration presents new problems. The optical requirements providing the most useful low-angle lights are in contrast to all safety regulations for a completely flush light. There are two mechanical necessities: a relatively simple and inexpensive installment, and an ability to withstand any load or impact, e. g., landing aircraft, snow plow blades, tailhooks, truck tire chains, etc. In addition, these lights must operate in all weather conditions.

The compact, high-lumen maintenance quartz iodine-cycle lamps meet all these requirements. They have to be installed in an 8-inch diameter, 1-inch deep recess with a 3/8 inch width, 1-inch deep slot connecting recess and serving as wireway to connect light and transformer. The inserted light presents a gradually sloped profile protruding only 1/8 inch above the runway surface. Of all possible optical systems, a lens giving higher beam candlepower and better performance at low angles was chosen. This particular light is being installed for field evaluations in several USAF runways.

REFERENCE

McKelvey, R. K., Brown, G. S., & Ontiveros, R. J.
Simulation comparison of three runway landing zone
lighting patterns. Atlantic City: Federal Aviation
Agency, Bureau of Research and Development,
April 1961. (Draft Report, Task 411-3-4R)

PURPOSE

The purpose of this study was to compare, using a visual landing simulator, three runway landing zone lighting patterns with respect to their efficiency in providing pilots with information necessary to maintain an optimal flight attitude for landing.

SUMMARY

Procedure The Dalto Visual Simulator was used for the visual presentation of different approach and runway lighting configurations. This was done with a TV camera which projected on a screen pictures of experimental lighting patterns. The patterns were mounted on a moving belt. The TV camera was synchronized electrically to the PV-3 computer for response to the pilots' control movements. The controls which the subjects manipulated were contained in the Curtiss-Wright P-3A Flight Duplicator, which provides a single seat cockpit environment and standard flight instruments.

The three runway patterns tested were as follows:

Narrow Gauge with Centerline (Configuration I) - A 60-foot narrow gauge lighting system extended the length of the runway (3,000 feet). Barrette units were 10 feet long and composed of three lights.

Units were installed at 100-foot intervals down the runway and oriented perpendicular to direction of landing. A centerline of lights placed at 20-foot intervals extended the runway length.

Narrow Gauge With Parallel Rows and Crossbars (Configuration II) - The first 1,000 feet of runway was patterned exactly as Configuration I. Fifty feet beyond the final pair of narrow gauge barrettes began a new pattern which continued for the remaining 2,000 feet of runway. This part of the pattern consisted of 60-foot crossbars perpendicular to the centerline of 200-foot intervals. Also the centerline was supplemented by two lines on either side and parallel to the centerline. These additional lines of lights were on a 60-foot gauge and units were separated by 25-foot intervals.

Crossbar and Cross-Pip System (Configuration III) - System consists of three elements: a continuous centerline of lights 20 feet apart, light units 20 feet in length (cross pips) which intersect the centerline at 200-foot intervals, and crossbars of lights which intersect the centerline at three places: 1,000, 2,000, and 3,000 feet. The crossbars are 140 feet wide and consist of 15 lights at 10-foot intervals.

Twelve NAFEC pilots served as subjects in the experiment. They were briefed regarding the purpose of the study and were told that on most approaches, the experimenter would effect a displacement on each axis of flight: heading, roll, or pitch. They were told that when this occurred, they were to make a corrective maneuver appropriate to maintain optimal landing conditions.

The Instrument Landing System was utilized by the pilot in each approach to the landing runway. The subjects were positioned

5 miles outside the outer marker at a flight attitude of 1,500 feet. Ceiling was kept constant at 400 feet, and runway visual range at 1,300 feet. Transition from instrument to visual flight was accomplished shortly after passing the middle marker.

The experimenter randomly introduced the roll displacement variable when the subjects were over the approach lighting with the runway in view. Heading and attitude displacements were introduced while the subjects were still on ILS and appropriate corrective action was made, if recognized. If the pilot recognized the displacement, he would take the necessary corrective action. The experimenters scored the subjects using a flight performance check list. Each subject made eight approaches on each of the three patterns. After the experiment, the subjects were asked to fill out a questionnaire which requested general comments on the three configurations.

Results The data from the flight performance check lists suggest a significant difference between the systems in providing information which allows the pilot to avoid undershoots and overshoots, favoring Patterns I and II. The systems were not significantly different regarding "rate of execution", or "steering", or "roll-out" information. There were slight differences regarding "rate of closure" and "height" information, Pattern I being superior to Patterns II and III. Pattern III appeared to be inadequate in providing both rate and distance information.

Results of the pilots' preference information obtained from the questionnaire show a preference (not statistically significant) for Pattern I. The ranking obtained was I, II, III - the same results were obtained, i.e., I, II, and III, in describing order of preference, when preference for VFR applications and use as the common pattern for marking or lighting were analyzed.

The question was asked whether the systems were well integrated (1) naturally, and (2) with the approach lighting. The responses to both questions differed significantly with respect to patterns with negative reactions to Pattern II. The implication, according to the authors, is that a piecemeal approach to display design is not consistent with the pilots' need for continuity of information.

Pilots' preferences changed with practice on the systems from Pattern II to Pattern I. This shift agrees with pilots' reports of changes in attitude towards the patterns.

A plan view of the landing zone light patterns is illustrated in Figure 10 on page I-27 of this report.

REFERENCE

McKelvey, R. K., Brown, G. S., & Ontiveros, R. J.
Simulator comparison of narrow gauge landing zone
lighting patterns in longitudinal vs. lateral arrays.
Atlantic City: Federal Aviation Agency, Bureau of
Research and Development, May 1, 1961. (Draft Report,
Task 411-3-4R, Problem 1)

PURPOSE

This study was designed to compare three experimental narrow gauge landing zone lighting patterns and one conventional edge lighted runway. The comparisons were with respect to the visual guidance offered in correcting for roll, pitch, and heading displacements. The patterns were presented by a visual simulation technique.

SUMMARY

Procedures The Dalto Visual Simulator was used for the visual presentation of different approach and runway lighting configurations. This was accomplished by a TV projected picture of advancing lights carried by a belt which simulated the landing zone light patterns. The TV camera was synchronized electrically to the pilots' responding control movements. The controls which the subjects manipulated were contained in the Curtiss-Wright P-3A Flight Duplicator which provided a single cockpit environment with standard flight instruments. The simulated lighting patterns compared were the following:

Distance Coded Discontinuous Longitudinal Array (Configuration E) - The runway centerline is defined by 120-foot bars longitudinally oriented and placed at intervals of 80 feet. The first 1,000 feet of runway is defined by five pairs of longitudinal bars placed on either side of the centerline. Each pair consists of three parallel rows of 100 feet long, with a 10-foot separation between the rows. These pairs of rows are positioned so as to alternate with the occurrence of centerline bars. The second 1,000 feet of runway is defined similarly except that there are two rather than three rows of lights in each pair, and the final 1,000 feet is defined by single rows.

Distance Coded Continuous Longitudinal Arrays (Configuration F) - This pattern is essentially that of Configuration E, except that the longitudinal rows are not interrupted but form continuous strings of lights (20-foot intervals). Centerline is continuous. The first pair of rows paralleling the centerline extend 3,000 feet; the second pair extend for 2,000 feet; and a third pair of rows extend only the first 1,000 feet of runway.

Narrow Gauge Lateral Array (Configuration G) - A continuous centerline extends the length of the runway. Pairs of laterally oriented barrettes are placed at 100-foot intervals, the length of the runway on a 40-foot gauge.

Conventional Runway (Configuration N) - Standard edge lighting, threshold lighting, no pattern in runway surface.

Twelve NAFEC pilots served as subjects in the experiment. Each subject had a one-hour familiarization session on the simulator. The subjects were then briefed regarding the purpose of the experiment.

The pilots were then positioned appropriately 5 miles outside the outer marker, at 1,500 feet altitude. Ceiling and runway visual

range were kept constant at 400 feet and 300 feet, respectively. Shortly after passing the middle marker, the transition from instrument to visual flight was made.

Runway configurations were changed after every three approaches. Each subject made a total of 18 approaches on each configuration. The displacement variables were introduced randomly on different trials, and an observer noted whether appropriate corrective action was taken. The results were analyzed to determine the pilots' ability to obtain appropriate roll and displacement information from the visual display. Heading and attitude corrections were made from information obtained from instrument displays.

Results Statistical analysis of the performance data shows no significant differences among the experimental patterns in effectiveness or providing heading and roll guidance, or in longitudinal positioning at touchdown. Both patterns "F" and "G", however, are significantly more effective than "N", the untreated runway.

For attitude guidance, the continuous system (F) and the lateral array narrow gauge system (G) are equally effective.

The most significant gain in effectiveness of the three experimental patterns was in controlling rate or descent at touchdown. Either of the longitudinal displays used here (E, F) was as effective as the lateral array in providing guidance for optimal vertical speed at touchdown.

Analysis of the pilots' preferences showed that the lateral array (G) and the discontinuous longitudinal array (E) were reversed from results obtained from performance data. The pilots' acceptance of "E" was greater than its effectiveness appeared from analysis of the test data. It must be noted, however, that a positive shift in preference from the earlier to the later trials occurred on this pattern.

The authors view this as a promising sign since it suggests that an initially strange pattern has the potential of being accepted with practice.

Most of the pilots expressed preferences for distance-coded displays, and patterns. "E" and "F" were the most strongly favored as a possible common pattern for marking and lighting.

Another conclusion strongly supported from pilots' opinions, and somewhat supported from the performance data, was the need for a compatible approach lighting and landing zone lighting system. Pilot's judgments on this point place the systems in the following descending order of preference: E = F > G > N.

Pattern "F", according to the authors, seems to offer stronger support for continued development than any of the other patterns.

Figure 11 on page I-30, illustrates the experimental patterns.

REFERENCE

McKelvey, R. K., & Ontiveros, R. J. Longitudinal spacing variables in "3:2:1" patterns for touchdown zone lighting. Atlantic City: Federal Aviation Agency, Aviation Research and Development Service, Research Division, December 1961. (Draft Report, Task 400-3-4R, Problem 2)

PURPOSE

Three distance-coded landing zone lighting patterns were compared in the Dalto visual landing simulator. The distance-coded patterns varied in degree and regularity of longitudinal spacing between light units and were compared in terms of pilot's ability to correct displacements in pitch, roll, and heading-line-of-flight; to control rate of closure, longitudinal positioning and vertical speed at touchdown.

SUMMARY

Procedures The Dalto/P-3A Simulator Complex was used to present the simulated runway patterns and to simulate an aircraft cockpit. The experimental patterns were as follows:

Configuration K - This pattern included wide spaced longitudinal arrays of lights to code runway distance. Light units were spaced at 100 foot intervals.

Configuration F - This pattern included close spaced longitudinal arrays, as light units were spaced at 20 foot intervals.

Configuration J - This was a mixed 3:2:1 pattern. The centerline was composed of lights on 20 foot centers, the first 1000 feet of

longitudinal lights were spaced on 100 foot centers, the remainder of the pattern consisted of lights in 25 foot centers.

The "pilot" was positioned approximately five miles beyond the outer marker on an ILS approach at 1500 feet altitude. Shortly after passing over the middle marker at .6 miles from threshold, the subject pilot shifted from instrument to visual reference. Displacements in pitch, roll, and heading-line-of-flight were introduced and the subject's task was to recognize these displacements on the basis of the visual pattern and to correct them by appropriate maneuvers.

Twelve NAFEC pilots participated in the experiment as subjects. Each pilot flew 18 approaches to each of the three patterns.

Data recorded were corrections in heading, roll and pitch; rate of maneuver execution; rate of closure; vertical speed and longitudinal positioning at touchdown. Pilot's were also asked to express their preferences for the systems.

Results The close-spaced configuration (F) was most effective in providing information necessary to correct rotational displacements and to control rate of execution of the corrective maneuver. No significant differences were detected among the three patterns in provided information for controlling rate of closure, vertical speed and a longitudinal positioning at touchdown.

Although the differences were not statistically significant, the preference data consistently ranked Configuration F above the other two.

The three distance-coded patterns are illustrated in Figure 12 on page I-32 of this report.

REFERENCE

Miller, H. R. Approach and runway lighting as viewed by the airline pilot. J. Air Transport Division. Proceedings of the American Society of Civil Engineers, 1959, 85 (AT3), 177 -179.

PURPOSE

The author lists recommendations for airport lighting improvements and comments on the usefulness of some of these changes.

SUMMARY

Recommendations for improvements in airport lighting system are as follows:

The use of distinctive, high intensity runway lights in order not to confuse them with street and miscellaneous lights or their reflections.

Runway lights effective in ice and snow.

Runway lights effective for daytime under poor visibility.

Runways preventing glare reflection.

Distinctive taxi strip lights.

Distinctive taxi strip designations for day and night.

Suggestions for improved approach and runway lighting are as follows:

Single row of approach lights on extended runway centerline.

Approach lights at a minimum distance of 3,000 feet starting from ends of principal runways.

System to be visible through 180 degrees (90 degrees to either side of the pathway).

System instantaneously identified under all conditions of visibility.

Runway lights having a beam spread at least equal to AGA type runway lights.

Runway plainly visible when circling through 360 degrees and when approaching at 90 degrees to runway.

Increase efficiency of runway lights during all weather conditions.

Only runway in use to be lighted.

All runway lights to be controlled by the main operator.

REFERENCE

National Aviation Facilities Experimental Center. Runway touchdown zone lighting for Dulles airport. Atlantic City: Federal Aviation Agency, Bureau of Research and Development, August 1960.

PURPOSE

The purpose of this study was to determine the adequacy of five lighting systems in providing visual guidance under visibility conditions below current minimum and to recommend a runway lighting system for Dulles International Airport.

SUMMARY

Procedure Five systems of runway lighting configurations were compared. System A, the one eventually recommended for adoption, will be described in the present summary. For information regarding the other four systems, the reader should consult the report itself.

System A consisted of 2,000 feet of MC-2 fixtures, 100-foot spacing, 65-foot gauge, 8,000-foot pancake centerline at 20-foot spacing, with taxiway exit having pancake units at 10-foot spacing.

A total of 30 airline pilots served as subjects. Theodolite data measuring pilot performance were used as one of the criteria in the evaluation of the systems. In addition, post-flight questionnaires, rating the five systems with regard to several aspects of guidance provided, were completed by the subjects. The test flights were made at night using a smoke generator to simulate a low-visibility fog environment.

Results The following conclusions were reached, based upon theodolite records and questionnaire data, both of these criteria being equally weighted:

A pancake centerline system provides continuous guidance during take-off and landing.

At least 1,000 feet of high intensity lighting is required in the runway to give guidance from the approach light system to the runway, 20,000 candlepower being the minimum required.

The spacing of taxiway pancake lights 10 feet apart clearly defines the curved portion of the exit.

The report offered the following recommendations for Dulles:

Pancake centerline bi-directional lights should be installed in series at 25-foot intervals. The fixtures should have a horizontal and vertical beam spread of 25 to 30 degrees and 20 to 30 degrees respectively. Interchangeable 45-watt and 100-watt quartz lamps should serve as the light source.

One thousand feet of 60-foot narrow gauge and three barrettes spaced at 100-foot intervals should be installed for pilot transition ease from approach lights to the runway lights.

A plan view of System A is presented as Figure 9 on page I-26 of this report.

REFERENCE

Simeroth, J. W., & Davis, J. E. Field tests of runway distance markers constructed by NAS Cecil Field. Washington, D. C.: National Bureau of Standards, July 1960. (National Bureau of Standards Report No. 6904)

PURPOSE

Field tests were performed to determine the visibility of internally illuminated runway distance markers and to compare these results with the visibility of standard markers.

SUMMARY

Procedure One of the internally illuminated runway distance markers was installed at the Arcata Airport on the left side of the runway, 2,000 feet from the threshold. The marker was an isosceles triangle, internally lighted by four lamps.

Observations were made from a vehicle moving along the centerline of the runway. The following data were recorded for each observation run:

Detection range - The greatest distance at which the observer could detect the presence of a numeral on the marker.

Recognition range - The greatest distance at which the numeral was legible with reasonable certainty.

Conspicuous range - The greatest distance at which an observer could unmistakably read the numeral at a glance while traveling at a speed of 40 to 45 mph. Observations were made in both daytime and nighttime conditions.

Results There was little difference in the detection and recognition ranges for the three methods of marking. The internally illuminated marker provided much better visibility ranges for nighttime operations than the standard marker, but for daytime observations the visual ranges estimated from the Cecil Field markers were slightly less than the ranges of the standard marker.

The preferred lamp arrangement depended on the particular number used on the marker. For visibility ranges of 1/4 mile or better, the internally illuminated marker is adequate for daytime and nighttime operations.

The internally illuminated marker presents no special glare problem as reported by the subjects, but the brightness obtained from lamps operating at constant intensity is not sufficient for all visibility conditions.

REFERENCE

Sparke, J. W. Surface lights for runways and taxiways.
A comparison of the merits and possible applications
of the "blister" and "pancake" types of light. Farnborough,
Eng. : Royal Aircraft Establishment, March 1961.
(Technical Memorandum No. EL. 1851)

PURPOSE

This report is a theoretical analysis of the merits and possible applications of the "blister" and "pancake" types of lights.

SUMMARY

"Blister" lights, originally called "contact" lights, project between 5/8 inches and 3/4 inches above the surface of the runway and take the form of cast iron or aluminum pots with a mounting flange on top. They produce a cylindrical beam up to 10 degrees above the horizontal and are normally omnidirectional and are made to show colored light by the inclusion of a filter.

"Pancake" lights are normally thin, cast iron discs mounted level to the runway. Light through channels in the disc can be seen over comparatively wide sectors from either runway direction.

At maximum output, the two types of fittings theoretically emit substantially the same quantity of luminous flux despite different light distributions. Pancake lights will probably result in increased glares when used at high wattages (100 to 200 watts).

With blister lights, there is an increasingly rapid fall-off in intensity at angles of elevation exceeding 4 degrees, and their

performance is likely to deteriorate fairly rapidly due to external contamination of the windows.

In marginal visibility by day, pancake lights will normally be visible at ranges somewhat less than meteorological visibility, and it is easier to install pancake lights on present runways.

REFERENCE

Strong, R. L. Category III test of an integrated visual approach and landing aids (IVALA) system. Westover Air Force Base, Mass.: Eighth Air Force, Strategic Air Command, June 1959.

PURPOSE

The purpose of the report was to describe a series of tests conducted at Dow Air Force Base to evaluate the Integrated Visual Approach and Landing Aids System.

SUMMARY

The report is a detailed compilation of the tests, the methods of tests, the resulting data, conclusions and recommendations concerning all components of the IVALA system. This annotation will present some of the general results of the tests and conclusions about the more critical components of the system.

General Results of System Tests

Using only ground-controlled approach as a primary approach facility, Configuration "A" Approach Lighting System with strobes provided early system identification and necessary visual information so that aircraft could be brought safely down to a range of 1/4 mile. From this point, narrow gauge flush runway lighting provided necessary height, roll, and directional guidance for the landing, even under reported zero visibility conditions. Centerline run-out lights, an essential component of the integrated system, insured directional

control following touchdown for all types of aircraft. Transverse roll guidance bars were found to be an undesirable addition to the approach lighting complex.

Analysis revealed that with system familiarization, both instrument and VFR weather minimums can be lowered. During initial approach, the strobe lights made system identification possible as far out as four times the reported visibility. Once established in the approach pattern, no difficulty was encountered by pilots of any type aircraft in visibility completing the balance of the approach, flare, and landing in visibility conditions down to 800 feet RVR.

Results of Component Tests

Narrow Gauge Lighting System - The combined Narrow Gauge/ Configuration "A" Lighting System provided essential and adequate all-weather approach and landing guidance to pilots of all types of aircraft.

The Narrow Gauge Lighting System, augmented by Configuration "A" with strobes, is capable of safely recovering aircraft under runway visual range conditions of 700 feet, when precision electronic approach aids are available that will provide guidance down to 100-foot ceiling and 1300-foot RVR visibility or to aircraft critical altitude, whichever is lower.

The Narrow Gauge Lighting System, as tested, was satisfactory in all respects; however, modifications can be made to further enhance system usability and to offer an improved visual presentation to the pilots of all types of aircraft. These modifications include:

Centerline run-out lighting.

A longer Narrow Gauge Lighting System to accommodate the larger jet aircraft.

A 200-foot longitudinal spacing for military operations.

Minor runway fixtures realignment.

Class C-2 fixtures (2-lamp), throughout the system for higher cut-off and brighter lighting.

Height guidance obtained from the Narrow Gauge Lighting System enables pilots to accomplish better landings during night visual flight conditions than can normally be accomplished using aircraft landing lights. The well-defined touchdown area also permits early alignment and will appreciably reduce the possibility of short landings under night clear weather conditions.

The sharp lateral cut-off characteristics of the Class "C" fixture is operationally satisfactory when installed as a part of the Narrow Gauge Lighting System. Directional information is provided at all times to the pilot relative to the location of the runway centerline when aircraft are positioned within a safe zone for the continuation of the approach.

The overall effectiveness of the Narrow Gauge Lighting System was not significantly affected by the extreme weather conditions in the north climates. However, both the flush and semi-flush fixtures were occasionally unusable because of high winds and extreme temperatures during moderate to heavy snowfall.

The Class "C" fixture provides a safe, efficient light source in the landing area and does not affect aircraft-handling characteristics nor present a safety hazard during touchdown, landing, run-out, or take-off for any current operational type aircraft.

Configuration "A" Approach Lighting - The Configuration "A" Approach Lighting System is an excellent visual approach aid and will make it feasible to lower the instrument minimums at bases equipped

with the system. The assistance provided by this system to the pilot is more apparent during periods of darkness due to the high contrast factors. Although day, high brightness instrument conditions presented the least contrast, an appreciable amount of assistance was provided.

During night instrument conditions, the Configuration "A" Approach Lighting System with strobes is visible to the pilot approximately three to four times the reported meteorological visibility. At the point of first contact, pilots were able to correct toward, and/or transition to, the lighting complex and to continue the approach visually.

During daylight instrument conditions, the Configuration "A" Approach Lighting System with strobes is visible from a distance half again as far as the reported meteorological visibility. Pilots are again able to transition to the system and continue their approach visually.

The phi phenomenon presented by the condenser discharge lights permits earlier system identification than is provided by the steady-burning incandescent lights on maximum intensity.

The use of position 5 on the approach lighting intensities minimizes the effectiveness of the strobe lights and is considered undesirable. During high brightness, poor visibility conditions, maximum intensities were required in the underrun area only.

Pre-threshold light bars provide no useful information to pilots approaching the 300-foot wide runway under either instrument or visual flight conditions.

The red termination bar stimulates undesirable pilot reactions at a critical point in instrument flight.

A spacing range, varying from 10 feet to 14 feet, is considered the optimum for runway threshold installation.

A direct comparison of snow problem areas could not be made; however, neither flush fixture presented a serious problem during normal snowfall periods. In extreme weather conditions, both fixtures could become operationally unusable. Under these conditions, the Class "B" fixture was slightly less dependable than the Class "C" fixture.

Centerline Run-Out Lighting System - The requirement for completely flush centerline run-out lights can be fulfilled by closely-spaced, low wattage lights. When properly spaced, these lights present a linear effect to the pilot.

The system installed provided adequate run-out information during visibility conditions of 1/8 mile during both daylight and darkness conditions, for aircraft with cockpit heights of 20 feet or above. During night, low visibility conditions, reflected light from fog or snow provided visible light, without requiring reference to the direct light source, thereby increasing the effective distance of the lighting system.

The lower limit of the light beam is visible at an angle of 4 degrees above the runway, which is insufficient for aircraft with cockpit heights of less than 20 feet. For effective, all visibility run-out and take-off directional guidance, a low beam angle of 2 degrees is required.

Transverse Roll Guidance Bars - Pilots found roll guidance information presented by Configuration "A" lights adequate for approaches under both instrument and visual conditions. Additional roll guidance was not required under actual weather approaches down to zero visibility conditions.

The addition of roll guidance bars materially changes the appearance of the Configuration "A" Lighting System, needlessly

complicates the pilot's visual interpretative problems, and could cause misinterpretation during poor visibility conditions when observed by pilots unfamiliar with the roll bar system. Therefore, the use of this additional lighting is contrary to the concepts of sound safety and standardization.

A plan view of the IVALA system is illustrated in Figure 7 on page I-22.

REFERENCE

Van O'osterom, T. Flight operational evaluation of approach and runway lighting systems. Lecture given to the International Aviation Research and Development Symposium of the Federal Aviation Agency in Atlantic City on April 12, 1961.

PURPOSE

The present study was undertaken to investigate the qualities of the proposed Netherlands approach and runway lighting system and to compare it with two alternative systems. This was done by means of instrumented, full-scale flight tests.

SUMMARY

Procedure. The flight tests were performed with a C-47 aircraft in northern Netherlands. The three lighting configurations compared were:

A. ALPA approach system - The approach configuration barrettes of lights were installed over a length of 3,000 feet along the centerline extension of the runway beyond the hard surface at intervals of 100 feet. At a distance of 1,000 feet before the runway threshold is a longer crossbar. The runway configuration consists of a 60-foot system. Barrettes are positioned at intervals of 200 feet over 2,500 feet of runway.

B. Netherlands proposal - The approach configuration is identical to system C for the first 2,000 feet, i. e., centerline barrettes with crossbars at 500-foot intervals. The inner 1,000 feet of the approach system consists of three longitudinal rows of barrettes in red with a white crossbar at 500 feet before the threshold. At 500 feet from threshold, a red "T" configuration interrupts the centerline.

The threshold itself is marked by a green bar. The runway lighting configuration consists of 75-foot narrow gauge of longitudinally oriented barrettes. A pair of these barrettes is positioned at 175-foot intervals along the runway surface. The runway edge is defined by longitudinal bars of 250 feet length which alternate with two standard runway lights. The beginning point on the runway is defined by the insertion of a pair of laterally oriented barrettes which connect the longitudinal barrettes with the runway edge bar.

C. Centerline and crossbar (CALVERT) system - The approach configuration consists of 3,000 feet of centerline barrettes with long crossbars at 500-foot intervals. The crossbar at 1,000 feet before the threshold is in red lights, while the threshold is marked with green barrettes. The runway configuration is a 75-foot narrow gauge system. Barrettes are placed at 250-foot intervals over 2,500 feet of runway. The aiming point for touchdown is indicated by a pair of oversized barrettes.

Eighteen pilots from ten different companies and government institutions served as test subjects although two pilots could not complete their test series because of weather conditions. The influence of initial flight condition was randomized by having approaches performed from three different starting positions. In order to conduct the tests under marginal weather conditions, a method of simulating such conditions was attempted. A screen was fitted to the cockpit window, limiting the pilot's angle of view in order to obtain a constant visual range as prevailing in homogeneous fog. The screen was raised slowly during approach in order to avoid the reduction of the visual range as the aircraft descends. In order to simulate visual conditions in fog, a clear neutral filter (10 percent transmission), together with a slightly diffusing sheet of perspex, was placed in the head support 4 inches from the pilot's eyes. The pilot retained an unobstructed view of the instrument panel.

In order to record the flight path, one multiple trace recorder and two photographic observers were used. The following events were recorded:

Course indicator deflections

Heartbeat signal

Event marker for ground speed calculations and for indicating time of touchdown

Evaluation of the efficiency of the different configurations was based on the following:

Quality of approach and landing, as defined by:

Actual flight path in horizontal and vertical projection until touchdown;

Height when passing runway threshold;

Vertical acceleration of impact at threshold.

Pilot effort, as defined by:

Total deflection of elevators, rudder, and ailerons;

Frequency of pilot's heartbeat.

Results The statistical data, obtained from the instruments' recording of flight path, indicate that altitude at threshold was closest to the ideal height for system B and farthest from the ideal for system C.

Analysis of flight path recordings did not show real differences since the authors suggest much data was lacking due to overshoots.

Analysis of the heartbeat recordings show that the heartbeat frequencies for system C were significantly higher than for system A.

The subjects indicated that the simulator equipment provides a very realistic simulation of the visibility in fog.

REMARKS

The weights assigned to the several criterion measures, in drawing conclusions about the different configurations, were not presented.

A plan view of the lighting systems is illustrated in Figure 8 on page I-24. It should be noted that the systems "ALPA", "NETHERLANDS", and "CALVERT" are also coded A, B, and C, respectively.

REFERENCE

Vaughan, R. T., Russell, S. B., & Douglas, C. A. A field evaluation of the relative brightness of eight types of runway marking materials. Washington, D. C.: National Bureau of Standards, October 1959. (National Bureau of Standards Report No. 6549)

PURPOSE

This report contains descriptions of comparison tests of eight types of runway marking materials and recommendations based on the test results. The touchdown area of a heavily used asphalt runway was used for evaluation of the materials.

SUMMARY

Procedure The following eight types of marking materials were included in the evaluation:

- Masonry paint with beads.
- Traffic paint with beads.
- Traffic paint.
- Traffic paint with "high-index" beads.
- Cemented plastic material containing imbedded beads.
- Masonry paint.
- Reflective aggregate binders with reflective aggregate.
- Thermosetting plastic.

Detailed descriptions of methods of application are given in the report.

A truck equipped with an observation platform and two booms with 600-watt aircraft landing lights was used for the evaluation tests. The centerline and side bars of the runway pattern were painted with the test materials.

A photograph was made of the test bars while the illumination and brightness on the bars were measured from the platform by

observers. The nighttime measurements were made under three lighting conditions: floodlighting only, outboard landing lights only, and inboard landing lights only. Daylight measurements were taken of brightness of the bars under wet and dry conditions. During the test period, there were no snow plow activities and no jet operations. The test materials were principally designed to measure performance of the materials in the touchdown area of the heavily used asphalt runway.

Results The most practical material for use as centerline markings in the touchdown area of a heavily used runway is the cheapest retroreflective material obtainable.

Under all conditions measured except outboard light conditions, the cemented plastic strips, masonry paint, and masonry paint with beads gave the poorest performance for side bars or narrow gauge markings.

For best all-around performance, traffic paint with beads, traffic beads with high-index beads, or reflective aggregate were recommended.

The reflective property and therefore the brightness of all the materials when wet depends to a considerable extent on the amount of water on the surface of the materials. All the materials under water appeared darker than when dry.

REFERENCE

Veerling, J. P. Runway lighting - New York International Airport. J. Air Transport Division. Proceedings of the American Society of Civil Engineers, 1959, 85 (AT3), 175-176.

PURPOSE

The author summarizes the new features used in the most recent remodeling of the New York International Airport.

SUMMARY

The newly remodeled airport runway, parallel to and 3,000 feet east of the present 4L-22R, has the following lighting features: Elfaka type narrow gauge lighting; high-intensity runway lights spaced 100 feet apart and 150 feet laterally; four high-speed turnoffs located 3,330 feet and 5,730 feet from threshold at point of turn; and surface mounted, low intensity, closely spaced lights, illuminating centerline of high-speed exit from point of turn on the runway.

The control systems used in this airport have their own features, such as: narrow-gauge operating on 100 or 200-foot spacing as desired; positive indication for controllers that current is flowing to both narrow gauge and runway edge lights; automatic stepdown from maximum brilliance to 25 percent after 15 minutes; automatic turnoff of Elfaka fixture heater after 1 hour, and elapsed timers of Elfaka light.

It was generally concluded that the gains from these improvements far exceed the added costs.

Miscellaneous

REFERENCE

British Standards Institution. Guide to civil land aerodrome lighting. London: Author, 1960. (British Standard No. 1332:1960)

PURPOSE

This guide was compiled in order to disseminate information concerning specifications and descriptions of airport lighting.

SUMMARY

Various types of design guides to meet the operating requirements of fixed wing aircraft and airports are described. Installation requirements are set forth for the various lighting systems and components. The following systems, components, and requirements are considered:

Basic requirements for aerodrome lighting

High intensity and low intensity lighting systems

Light beacons

Runway alignment beacons

Hazard beacons

Approach lighting

Angle of approach indicator systems

Runway lighting

Circling guidance lighting

Taxiing lighting and guidance

Obstruction lighting

REFERENCE

Calvert, E. S. Safety and regularity in landing. J. Royal Aeronautical Society, 1959, 63, 690-695.

PURPOSE

This paper was presented to stimulate interest and discussion in take-off and landing safety. It specifies some of the visual problems (elements of visual guidance) encountered by the pilot and suggests solutions to these problems.

SUMMARY

Elements of Visual Guidance - Displacement of a pilot above or below glide path results in an extension or compression of the visual image, not in an unique asymmetry in the image. Vertical displacement is, therefore, much more difficult to detect than horizontal displacement.

In marginal visibility without a crossbar pattern, a pilot cannot usually recognize a dangerous situation in time to respond and, thereby, avert disaster. The accident rate for only lead-in lights, with no other visual aid, may be up to 100 times greater than that rate occurring when a crossbar pattern is used.

Implications for Safety Regulations and Practical Suggestions - The only way to effect a substantial increase in safety at difficult runways is through installation of an effective VGPI for use in visual ranges above 1 mile and a multiple crossbar pattern for use in visual ranges less than 1 mile. The author feels that no ground pattern

will give adequate guidance in the future but that it must be supplemented with a VGPI.

REFERENCE

Department of the Air Force. Construction. Visual air navigation facilities. Washington, D. C.: Author, May 1960. (Air Force Manual No. 88-14)

PURPOSE

This manual was compiled to provide technical information and guidance in designing, operating, and maintaining systems of visual guidance for aircraft pilots.

SUMMARY

The manual was presented in four parts as follows:

Introduction and description of guidance facilities and the development of standards upon which such facilities are provided.

Criteria for the design and installation of airfield lighting systems, including standard drawings.

Detailed description of the equipment used in the airfield lighting systems.

Criteria for design and placement of airfield markings, including pertinent technical data.

REFERENCE

Karns, E. B. Lighting of airport service areas. Illum.
Engng., 1960, 55 (10), 565-568. (Paper presented at the
National Technical Conference of the Illuminating Engineering
Society, September 11-16, 1960, Pittsburgh, Pa.)

PURPOSE

The author discussed service area tasks and illumination problems within airports.

SUMMARY

The primary functions of the service area lighting within an airport are:

- to enable pilots to guide their aircrafts into final positions for loading and service, and
- to provide lighting for personnel to load and unload passengers, cargo, and fuel and to perform other services.

In addition to providing general visibility, the avoidance of glare has to be considered when the illumination devices are installed. The most usual conditions for creating glare are:

- location of luminaires
- direction of light beam
- type of light source and luminaires

In order to avoid glare and to provide better visibility, luminaires of high brightness filament or mercury sources can be used when mounted as high as possible, the minimum being not less than 50 feet for flood-lights and 30 feet for other types of luminaires.

REFERENCE

Keyes, H. J. A review of the methods of measuring aircraft take-off and landing performance. London: Ministry of Aviation, Aeroplane and Armament Experimental Establishment, August 1960. (Report No. AAEE/Tech/119, ASTIA Document No. AD 243 782)

PURPOSE

Criteria for apparatus used to measure take-off and landing performance are presented and existing techniques are evaluated.

SUMMARY

Several methods of measuring aircraft take-off and landing performance were reviewed. Advantages and disadvantages of each method were noted. In addition, each method was evaluated with respect to how adequately it met the criteria of a good measuring system. The following criteria are specified:

Measurement records should be capable of quick and accurate analysis.

A minimum of fittings to the aircraft should be required.

Measuring system should be mobile, requiring no elaborate preparation.

The methods evaluated and the results of the evaluation follow:

1. F-47 camera located to one side of the runway and cine-photographs the aircraft as it moves along take-off or landing path.

Advantages - equipment is mobile and requires no special fittings on the test aircraft.

Disadvantages - reading of the film and subsequent analysis is long and tedious. Use of cine-camera restricts the method

to use during hours of relatively bright daylight. Large errors in velocity can be introduced by the aircraft swinging from the centerline of the runway.

2. Spider method - in this method a spool of thread is attached to the aircraft. Rate of movement of the aircraft is determined from the motion of a wheel over which the moving thread is passed.

Advantages - distance and velocity times can be obtained quickly.

Disadvantages - no suitable means of obtaining aircraft heights; no means of applying equipment to landing measurement.

3. Photo-electric cell method - in this method, a photo-electric cell beneath the aircraft responds to each of a series of lines painted at regular intervals across the runway.

Advantages - eliminates errors in derived airspeed.

Disadvantages - involves considerable work in marking runways; considerable fitting and test equipment on the aircraft is required.

4. Fairchild photographic flight analyses - consists of a wide-angle lens camera on one side of runway, with the lens pointing at right angles to the centerline. Aircraft are tracked through a pair of binoculars mounted on camera. Exact photographic panoramic display of aircraft's path is obtained.

Advantages - extremely accurate timing measurements.

Disadvantages - can be used only for aircraft with short take-off and landing distances.

5. Measurement of touchdown speed - this method employs a fixed cine-camera located to one side of runway, pointed at right angles to runway. Movement of aircraft, measured by reference to a graticule line in the lens system, enables the aircraft speed relative to the ground to be determined.

Advantages - accurate measurement; no elaborate fittings required on aircraft.

Disadvantages - touchdown must be made within the field of view of the camera.

6. Eclair cine-theodolite - a camera is set up to one side of the runway and an operator tracks the aircraft in azimuth and elevation. A cine-camera attached to the theodolite photographs the aircraft and can be used to assess its tracking accuracy.

Advantages - good accuracy in speed and tracking data; data can be analyzed rapidly; equipment is mobile and does not require equipment on the aircraft.

Disadvantages - errors can arise due to divergence of aircraft from centerline.

REFERENCE

National Bureau of Standards, Photometry and Colorimetry Section, Optics and Metrology Division. Development of visual landing aids for jet aircraft. Washington, D. C.: Author, June 1960. (Final Report, National Bureau of Standards Report No. 6862)

PURPOSE

This report contains a review of developments in visual landing aids and methods for installing them.

SUMMARY

This report specifies the visual aid requirements which an airport marking and lighting system should provide. It reviews field tests of lighting and marking systems and makes recommendations based upon these tests and upon pilot interviews. In addition to the field tests, theoretical issues, for which little data are available, are discussed.

Problems in Glare Control in Approach and Runway Light Systems - The maximum useful intensity of a signal light can be computed as a function of the atmospheric transmittance and the distance between the pilot and the light. When this distance is small, the maximum useful intensity is low in both fog and in good visibility. Thus, the lights of the inner approach zone will cause glare even in dense fog if they are operated at intensities higher than 5 percent of full intensity. However, if the intensity of the lights in the outer approach zone is reduced to 5 percent of full intensity when visibility is 1,000 feet, the pilot will not see the outer 1,000 feet of the approach light

system. It appears desirable, therefore, to have the lights in the outer zone operate at somewhat higher intensity than those in the inner zone.

Considerations in the Design of Runway Narrow Gauge and Centerline Lights - At an eye height of 15 feet (typical of large aircraft), all runway lights more distant than 500 feet are viewed at angles of elevation of less than 2 degrees. Therefore, centerline and the lights used after touchdown should be directed at an angle less than 2 degrees to maximize effectiveness. If lights are used in daylight conditions, the beam intensity of the centerline lights should be at least 500 candles. For night use only, the centerline lights should have an intensity of about 500 candles.

Considerations in the Design of Approach and Runway Lights - Although there is no one optimal intensity distribution pattern, each pattern being a function of the operational conditions on which it is based, certain requirements are applicable to all designs of intensity distribution patterns.

The elevation of the lower edge of the beams of the lower edge of the beams of approach lights should be no greater than the glide path angle.

The lower edge of the beams of both edge and inset runway and centerline lights should be approximately horizontal.

The outboard edge of the beams of runway edge and narrow gauge lights should be parallel to, or outboard of, the line of lights.

Location and Identification of the Runway - Several suggestions are offered as possible solutions to early location and identification of the runway. They are the following:

Lights should be installed at the ends of the rows of runway lights, coded to permit positive identification of them as runway identification lights.

Lights should be installed which have sufficient intensity in the off-runway direction when the system is operated at less than maximum intensity.

Flash frequency of the lights should be at least 40 flashes per minute.

In order to prevent glare, the effective intensity of the light for all azimuth angles greater than 10 degrees of the runway should not exceed 100 candles.

REFERENCE

National Bureau of Standards, Photometry and Colorimetry Section, Metrology Division. Development, testing, and evaluation of visual landing aids. Washington, D. C.: Author, April 1961. (Consolidated Progress Report for the Period January 1-March 31, 1961, National Bureau of Standards Report No. 7147)

PURPOSE

The report contains results of field tests of visual landing aids and information concerning test presently in progress.

SUMMARY

In this report, findings are reviewed of the effect of high-intensity airfield lighting on background luminance and horizontal illumination. Data obtained from positions near the runway indicate the following:

The amount of back-scatter light increases as visibility decreases down to about 2 miles visibility, remains fairly constant for visibilities between 1/4 and 2 miles, and then decreases again as visibility drops below 1/4 mile.

The back-scatter of light from the center row approach lights in a direction 2 degrees above the horizon directly over the light gives a maximum background brightness of 1-foot lambert or more.

The back-scatter of light from the runway lights, when measured in the same direction as for the approach lights, gives a maximum value of over 0.02 foot lambert.

Runway Turnoff Indicator - Field tests at Arcata have resulted in favorable reports from local pilots on the installation of several closely spaced runway lights on each side of the turnoff onto the taxiway. One turnoff has three runway lights on each side of the taxiway in line with the row of runway lights which are spaced at 10-foot intervals. Another turnoff was marked by using three runway lights along the edge of the taxiway, spaced at 10-foot intervals, with the beams of these lights aimed along the runway. Since only a few possible arrangements were investigated, the optimal spacing arrangement cannot yet be specified.

Test of 24-inch Beacon - Photometric tests were conducted on a 24-inch beacon manufactured by Westinghouse Electric Corporation. When used with a 1,200 watt lamp and an auxiliary reflector, the unit had a peak effective intensity of 100 kilocandles. The beam elevation was at 10 degrees vertical.

REMARKS

Other components and systems are discussed in the report. However, these have been omitted from the present annotation since they indicated work in progress and reported no field test data.

REFERENCE

Villiers, W. A. Developments in airport lighting.
Aeroplane, 1959, 96 (2470), 11-12.

PURPOSE

The author listed some requirements for a good landing, stated problems arising in proper airport marking and lighting, and described some of the recent developments and remodelings of the old systems for improving their shortcomings.

SUMMARY

In order to have good landing conditions, the pilot must be presented with an easily recognizable lighting pattern whose signals can be quickly and accurately interpreted. He needs to know three things: the location of the runway, the correct path and attitude for approaching it, and the exact limits of the runway itself.

There is a tendency toward increased beam angles from runway lights and away from high-power pencil beams. A much broader beam of about 25 degrees in azimuth is needed to give the pilot more control latitude. However, broader beams mean higher wattages and higher temperatures, which present special problems. Very few glass filters can produce satisfactory aviation colors since a slightly off-color filter changes appearance under certain weather conditions: some blues can look like greens; some ambers, like reds; some greens, like whites; etc. These changes are aggravated by high temperatures. Thus, a new type of glass should be constructed.

At present, there is a slightly confusing difference in appearance between approach and runway lighting systems. Up to now, runway lights (8,000 candelas) are of lower intensity than approach lights (80,000 candelas). The tendency is to bring runway lights up to 20,000 candelas and to have a dimming system on both in order to vary the amount of light according to weather conditions. Pilots need only to be brought to within 2 miles of the lights in normal visibility (1/2 mile previously) with this system, thus relieving the task of radio control.

Another development is in angle of approach indication, an area which has been ignored for the past years. Such an indication is especially useful in bad weather. Two AAI systems are presently in development: a three-color system, using the same light source with red, amber, and green sectors; the other being a two-color system with red and white bar indicators.

The Calvert system of bar and line lighting seems to be the best known approach lighting method. It stands up to 3,000 feet from the runway and provides the pilot with a "horizon" indicating the threshold where runway lighting takes over.

An important problem is the correct installation of lights: high intensity approach lights should not be mounted on poles that wave about in the wind; runway lights should not be left dirty or broken; etc. The author feels that if these problems were solved, even the more outdated lighting would be more effective for the safety and economy of airport lighting.

REFERENCE

Warskow, M. A. Jet airport lighting requirements. J. Air Transport Division, Proceedings of the American Society of Civil Engineers, 1959, 85 (AT4), 41-49.

PURPOSE

Remodeled or newly revised airport lighting equipment and standard aids for safe approaching, landing, and ground traffic control are discussed.

SUMMARY

Because of the increase in jet aircraft operations, the entire airport lighting system has to be either remodeled or changed completely to insure maximum safety for landing.

Approach and Landing - There is a need for better lighting of runways. In IFR conditions, the approach is made to a minimum altitude on instruments; then the pilot switches to VFR for completion of landing. The lowest minimum value, used only in Newark Airport, is 2,000 feet runway visual range with no specified ceilings. This is an exceptionally low minimum because of excellent electronic, visual, and weather report aides. The more common minimum is 200 feet ceiling and 1/2 mile visibility. FAA supports a number of research projects concentrating upon visual aid improvement, especially types of lighting needed for runways. These are some of the new concepts for improvements:

Flush grid type lights installed within pavement on a 60-foot gauge, with lights on a 100-foot longitudinal spacing; nearly completed at Dow Air Force Base.

Semi-flush, prism-type units, less expensive and less difficult to install. However, it creates a "bump" during snow removal and provides only a point of source of light.

Closely-spaced, low-intensity lights, utilizing greater numbers of units with less penetrating power for depth perception on touchdowns. They are very simple although the problem of providing adequate intensity for daylight fog conditions exists. This concept is being explored at the University of California.

Fluorescent floodlighting along the edges of runway in touchdown area is installed at Washington National Airport. It is helpful during night but inadequate for the daytime use because it can provide only a low intensity light at the runway center.

Ground Traffic Control - The present lighting for taxiways seems to be fairly adequate although it would seem an improvement to mark taxiway centerlines instead of edges. An improvement is needed in techniques for marking runway crossings.

Control Tower - A more adequate system indicating status of aircraft operations in addition to operations of light equipment is needed.

Control and Circuiting - Extensive remodeling is probable in these areas:

The use of automatic intensity control on approach and landing aids (approach lights, runway and narrow gauge lights, etc.). Intensity must be adjusted to weather conditions.

Weather-reporting equipment will be equipped with computers to translate weather data into useful visibility and ceiling measurements.

More reliable lighting systems are needed. Dual cable systems and automatic change-overs, using alternate circuiting of lighting around the runways, should be used.

REMARKS

This article includes illustrations of night view approach and runway lighting systems, illustrations of three circuits, and a map of New York International Airport.

Human Factors Research

Pattern Recognition

REFERENCE

Gaito, J. Visual discrimination of straight and curved lines.
Amer. J. Psychol., 1959, 72 (2), 236-242.

PURPOSE

Two experiments were conducted to test predictions of form discrimination thresholds based on an information theory approach.

SUMMARY

Procedure In the first experiment, three subjects were presented with straight and curved lines placed horizontally and vertically at 5 degrees to the left and 45 degrees to the right, exploring the foveal vision. An ascending series was used with exposure time increased until each subject correctly identified the forms.

In the second experiment, air crew personnel with normal vision were presented with four types of forms: straight lines, curved lines, triangular forms, and box-like forms. Their task was to identify the forms presented at visual angles from 6 minutes to 2 degrees 36 minutes.

Results The straight line has the lowest threshold; box and triangles, the largest; and curved lines, an intermediate threshold.

There is a tendency to perceive the more complex forms as simple forms and a strong tendency to report perception of a straight line for forms presented foveally or parafoveally.

REFERENCE

Rock, I., & Engelstein, P. A study of memory for visual form. Amer. J. Psychol., 1959, 72 (2), 221-229.

PURPOSE

These experiments were designed to answer the question of whether the trace of a visual form, representing the aspect of shape, changes or remains unchanged over a period of time.

SUMMARY

Procedure Seventeen college students were used as subjects in each test of the experiment. Each subject was presented an irregular geometrical figure, having a range of ten levels of similarity. Although he was informed that this was an experiment of extra-sensory perception, he was not told that he would later be called upon to recognize the figure. After different periods of time had elapsed (15 seconds, 1 day, 2 days, 1 week, 2 weeks, 3 weeks, 4 weeks), each subject was asked to select from the set of ten similar figures the one which he had previously been shown. A second experiment, using different figures, was conducted in the same manner as the one described above.

Results There was near-perfect recognition for the time duration out to three weeks. At that duration, only 3 of 17 subjects scored less than 10, a perfect score. (Possible scores ranged from 1 to 10.)

At four weeks, the longest time interval used, the median score was still 10, indicating that recognition was still excellent.

The results obtained on the second experiment were almost identical to the first except that at the longest time interval, the median score was 9, still indicating excellent performance.

The excellence of recognition with little decrement indicates that the whole memory trace, as far as it preserves phenomenal shape, remains unchanged.

No one form produced better performance than any other, indicating that similar configurations can be discriminated equally well over a period of time.

REFERENCE

Steedman, W. C., & Baker, C. A. Target size and visual recognition. Hum. Factors, 1960, 2 (3), 120-127.

PURPOSE

This study was designed to test ability to recognize a particular pattern form on a display containing many irrelevant forms. Speed and accuracy of pattern recognition were measured and related to displayed pattern size and resolution.

SUMMARY

Procedure Subjects were shown a standard pattern and problem displays in the form of partly filled-in matrix cells, varying the degree of blur or resolution and size. They were asked to locate and to indicate the form on the display that most closely resembled the standard pattern. Four resolution conditions were investigated: .00, .02, .04, and .08 respectively. The size of the problem displays varied from 1.95 to 7.8 inches. Both standard and problem patterns were manipulated on successive presentations by rotating them by 90-degree steps through 360 degrees. The errors and time needed to identify the correct pattern were recorded.

Results The most significant conclusions of this experiment indicate that both criterion measures, namely search time and errors, remained relatively invariant until the visual angle subtense of the maximum dimensions of the pattern fell below 12 minutes. Thus, if a 12-inch viewing distance is assumed, a target has to have a minimum

size of 0.042 inches, as displayed, in order to expect relatively accurate and rapid recognition.

The author assumes that if the smallest target that has to be recognized is 1,000 feet in its greatest dimension and that the system displays an analogue of a strip of ground 40 miles wide, the display must have one dimension of not less than 10.2 inches. On the other hand, if the critical target is 50 feet long and the displayed size is fixed at 10 inches, the ground range cannot exceed 2.1 miles.

The author concluded that 12 minutes of visual angle may be unrealistically small when the operational environment is considered. Thus, where practical, the minimum visual angle should probably approximate 20 minutes rather than the 12 minutes found in this investigation, since targets less than 12 minutes contribute 98 percent of the errors in this experiment.

Luminance and Visual Acuity

REFERENCE

Beck, J. Stimulus correlations for the judged illumination of a surface. J. exp. Psychol., 1959, 58 (4), 267-274.

PURPOSE

This study was designed to investigate the problem of how the judged illumination of a single surface varies with its actual illuminance.

The experiment sought to determine for surfaces with clearly perceptible pattern texture composed of two different light intensities, (1) whether subjects can make consistent judgments of surface illumination, and (2) whether variables can be revealed in the light array which will specify the subjects' judgments of illumination.

SUMMARY

Procedure The subjects were university students. The experiments required the subjects to adjust the illuminance of a comparison surface until its judged illumination matched a standard surface while both were viewed simultaneously and monocularly. The surfaces differed in lightness and were positioned so as to eliminate shadows. Therefore, the distinctness of the pattern textures was not affected by increasing illumination. After the subjects had made the illumination matches, they were then asked to match the lightness of the comparison and standard surface (whose illumination remained at the values used in the experiment) with a chart of 12 Hering grays which varied in reflectance from 8 percent to 78 percent.

Results Inspection of the obtained judgments indicated that subjects could make consistent judgments of the illumination of surfaces with clearly perceptible pattern textures. Changes in illuminance affected the subjects' judgment of illumination. However, changing the illuminance had little effect on the subjects' judgments of lightness.

There was a tendency for the judged illumination of a surface to be determined by the higher of the two intensities of light coming from the surface rather than to be determined by the average of the two intensities.

Since highlights, shadows, gradients, etc. were not available as cues to the subjects, changes in illumination were indicated only as changes in the lightness of the surface.

The results suggest the possibility of independently specifying the correlates for both the judged lightness and the illumination of a surface.

REFERENCE

Blackwell, H. R., & Bixel, G. A. The visibility of non-uniform target-background complexes. I. Preliminary experiments. Columbus: Ohio State University, April 1960. (RADC Technical Report No. 60-99, Contract No. AF 30 (602)-1974, ASTIA Document No. AD 246 740)

PURPOSE

The study investigated the possibility of assigning a "value of effective contrast" to represent the visibility of a target in a target-background complex in which target and background may be of non-uniform luminance.

SUMMARY

Blackwell has previously demonstrated that for simple targets of uniform luminance viewed against backgrounds of uniform luminance, targets of equal contrast, brighter and darker than their backgrounds, were essentially equal in detectability. For targets of non-uniform luminance viewed against backgrounds of uniform luminance, previous studies indicated that when a target of mixed contrast (non-uniform luminance) was viewed at sufficiently small angular subtense, the positive and negative contrast areas tended to cancel one another, causing the target to be difficult, if not impossible to detect.

Circular targets have been found least detectable when their physical size was approximately equal to the size of the light and shadow patterns of the backgrounds.

The author summarizes previous research by pointing out (Blackwell, ASTIA Document No. AD 246 740, page 4) ". . . that

much empirical and theoretical work will be required before we have even a reasonably complete understanding of the visibility of targets in target-background complexes of non-uniform luminance"

Procedure Several experiments were conducted to establish the threshold value of relative contrast and to establish the probability of target detection as functions of relative reflected light contrasts. The subjects were carefully measured with respect to corrected and uncorrected eyesight, and several trials were run according to psycho-physical methods. The methods used were the method of adjustment to threshold and the method of constant stimuli.

Results It was found that a value of effective contrast assigned at one level of luminance may be generalized to other luminances. This is to say that it would be meaningful and useful to develop methods for assigning values of effective contrast to represent the visibility of targets in target-background complexes of non-uniform luminance.

REFERENCE

Boardman, L. J. Effect of glare on eye behavior during growth of dark adaptation and during blackout conditions. Washington, D. C.: U. S. Naval Research Laboratory, Photometry Branch, Optics Division, April 21, 1961. (NRL Report No. 5613, ASTIA Document No. AD 255 725)

PURPOSE

This study was designed to investigate the effect of glare sources of various luminances on inspection of a test source of different luminances. The glare conditions under which blackout of the test figure would occur were of primary interest.

SUMMARY

Procedure Two small sources of light, 5 inches apart, were placed at normal reading distance from the subject's eyes. One source was the test field; the other, the glare. The luminances of both were varied over a wide range in order to determine the limits of the blackout conditions. For each level of field luminance, the luminance of the glare was raised until blackout occurred. Both red and tungsten glare light sources were used. The glare luminance was then increased by fairly equal steps, thereby producing longer duration of blackout, until the test field was lost in the halo of the glare and did not return. After each glare change, the eyes were allowed to dark adapt. Two conditions of observation were used: first, the eye constantly watching the glare source; second, the eye searching for the test field after the blackout with the glare light still on.

Results Recovery of dark adaptation is slower following exposure to white tungsten than to red illumination. Exposure to 3-10 foot-candles of tungsten is equivalent to 300 foot-candles of red illumination. A 20-fold increase in red luminance over white is required to produce a blackout condition. To produce loss of test field, the luminance of either red or tungsten glare sources had to be 150-fold greater when the subjects were permitted to search for the test field than when they were required to focus on the glare source.

REFERENCE

Bradley, R. C. New facts about glare from large-area light sources. A paper presented at the Third IERI Symposium, March 3-4, 1960, Washington, D. C.

PURPOSE

This experiment investigated the parameters of subjective level of discomfort for various light source sizes and surround brightnesses. Particular emphasis was placed on large area light sources.

SUMMARY

Procedure Four male engineering and service students, all trained observers (i. e., experienced in this type of subjective judgment task), were used in the experiment. The glare source was 8 feet square; composed of fifty-nine, 8-foot, 200-watt fluorescent lamps, each rated over 13,000 lumens. Built around the glare source was a cloth room, 9 feet square in cross section and 16 feet long. For the condition of glare in a dark surround, the room was lined with black cloth. For the glare condition in a light surround, the room was lined with a white cloth. The size of the glare source presented to the observers was varied by means of various sized lids being placed over the light source. Seated facing the glare source, the observers were allowed to control the source brightness through use of a toggle switch mounted on the chair. They were instructed not to fixate on the light source but rather to gaze fully about the room, and then they were dark adapted. With the source set a level below any perceptible glare, the subjects were next instructed to raise the brightness level through use of the toggle switch, after which

they verbally reported the point of "just perceptible glare". This point was recorded through the use of a photoelectric cell.

Results Size of the glare source had less effect on judgments of discomfort in dark surround than in light surround conditions. The size of the source had greater effect on higher rather than lower glare discomfort. For larger light sources in moderate surround brightnesses, a small change in source brightness caused a large change in glare discomfort.

REFERENCE

Heinemann, E. G. The relation of apparent brightness to the threshold for differences in luminance. J. exp. Psychol., 1961, 61 (5), 389-399.

PURPOSE

The effect of presenting a stimulus to one region of the retina upon the luminance difference sensitivity in a neighboring region was investigated. Several levels of illumination of the test field were investigated to determine difference limens (DLs).

SUMMARY

Procedure Two subjects, a man and a woman, served in the experiment. The stimulus arrangement consisted of three stimuli: the test field, the inducing field, and the increment field. The test field was an illuminated disc with a diameter of 30 minutes of visual angle. The inducing field, an illuminated annulus whose outer diameter was 1 degree 76 minutes of visual angle, surrounded the test field with its inner border contiguous with the outer edge of the test field. The increment field was a disc of 10 minutes of visual angle that could be superimposed on the test field. Just noticeable differences (jnd) were established by the method of limits.

In another experiment, the test field and inducing field were presented to each subject's right eye. Using a binocular viewing device, a comparison field was presented to the left eye. Each subject was required to fuse the two fixation points so that he saw a single fixation point with the comparison field on the left and the inducing

field on the right. He was then required to make brightness matches.

Results Test fields that are matched for apparent brightness remain matched when the luminance of each is raised or lowered by jnd steps.

For test fields of the same apparent brightness, the relative values of the DLs depend on the relative rates at which the apparent brightness of these test fields change with their actual illuminance. Stated in general terms, the results show that when a foveally presented test field is surrounded by an inducing field, the inducing field has three effects: (1) It changes the apparent brightness of the test field; (2) It changes the rate at which the apparent brightness of the test field changes as a function of changes in the illuminance falling on it; and (3) It alters the luminance difference threshold (DL) within the test field.

REFERENCE

Johansson, G., Backlund, F., & Bergström, S. S.
Luminance changes and visual acuity. Uppsala, Sweden:
University of Uppsala, The Psychological Laboratory,
March 1959. (Report No. 5)

PURPOSE

The purpose of this experiment was to investigate the time lag required to obtain maximum visual acuity, after luminance change, up to a glare level luminance.

SUMMARY

Procedure Three separate experiments were performed using the same apparatus. The subjects looked through an eyepiece and viewed a circular field. A test figure was placed on the field 573 millimeters from the eye.

The test figures used to determine visual acuity were of the checkerboard type with different size squares on the board. Visual acuity was defined as correctly stating the position of the checkered square on the test figure (bottom right, upper left, etc.). In the test, each subject viewed the test figure at one luminance level (preadaptation) until he correctly identified the position of the checkered square five times in succession. Then the luminance of the field and the position of the test figure were randomly changed. The time lag, the time between the attainment of maximum visual acuity at the preadaptation luminance and the determination of visual acuity at the test luminance, was measured. The luminances used were 1, 10, 100, 1,000, 2,000, 5,000, and 10,000 millilamberts.

Results For the test luminance of 1 millilambert, the time lag increases with increasing preadaptation luminance. With a preadaptation luminance of 10,000 millilamberts, subjects require about 90 seconds to achieve maximum visual acuity at a test field luminance of 1 millilambert. With a test luminance of 10,000 millilamberts, the time lag decreases with increasing preadaptation luminance. The variations in time lag, both between subjects and within a subject, are quite considerable. Very aberrant time lags occurred after a high luminance of a preceding measurement. This indicates that maximum visual acuity at a particular luminance does not mean perfect adaptation.

With maximum visual acuity as the criterion of adaptation, a high test luminance increases the time necessary to adapt to a subsequent test luminance.

Adaptation time was greatest in 80 out of 100 measurements for a 3-second glare duration and in 91 out of 100 measurements for a 6-second glare duration.

Results of these studies indicate that the effect of a certain luminance change on the time lag in a subject's visual acuity cannot be accurately predicted since the time lag might be influenced by earlier glares. If the glares to which each subject has been exposed... are of sufficiently long duration for the subject to attain maximum visual acuity, the time lag may sometimes rise to 1 or 2 minutes when the luminance is changed.

REFERENCE

Kaplan, I. T., & Ripps, H. Effect on visual threshold of light outside the test area. J. exp. Psychol., 1960, 60 (5), 284-289.

PURPOSE

The authors studied the influence upon the test threshold of the luminance, number, and location of inducers in the foveal and peripheral area.

SUMMARY

Procedure Two males, one emmetropic and the other wearing glasses to correct myopia, were seated in a dark room for 10 minutes before foveal determinations and for 30 minutes before peripheral determinations. The inducers, 10 feet in diameter with the distance between the center inducer and the center of the test field being 25 feet, were on continuously while the test field was flashed. Test luminance was altered by .05 log unit steps until each subject's response changed from negative to positive or vice versa. The induction luminance varied from -2.70 to +3.51 log millilamberts in the fovea and from -4.49 to +3.73 log millilamberts in the periphery.

Results Generally, the test threshold rose as the inducing luminance increased. It also rose as the number of inducers increased, but successive inducers produced decreasing increments in the log luminance.

The rise in test threshold, produced by a given number of inducers, increased as the distance between the inducers was increased. In addition, variations in luminance and number or location of inducers produced larger effects in peripheral sensitivity than in foveal sensitivity.

For the fovea, the luminance thresholds were higher than inducers with no changes until the inducing luminance reached -. 62 log millilamberts. Test thresholds rose as the number of inducers increased, but successive inducers produced decreasing increments in threshold log luminance.

For the periphery, the inducers were not visible at -4. 49 log millilamberts, thresholds being slightly lower than without inducers. They were dimly visible at -3. 46 log millilamberts. As inducing log luminance increased, the rate of rise in threshold log luminance first increased, then decreased, and then increased again. The range of peripheral thresholds was larger than for foveal. Without inducers peripheral threshold was 1 log millilambert less than for the foveal threshold.

REFERENCE

Lit, A. The effect of fixation conditions on depth discrimination thresholds at scotopic and photopic illuminance levels.
J. exp. Psychol., 1959, 58 (6), 476-481.

PURPOSE

This study investigated the precision of depth discrimination and the effect of three conditions of fixation on the magnitude of the stereoscopic threshold angle.

SUMMARY

Procedure Two pretrained students with normal visual acuity and good binocular functioning were presented with two targets, blackened steel rods 1/4 inch in diameter. A "comparison" rod was located in the lower half of each subject's visual field; a "standard" rod, in the upper. Subjects adjusted the depth position of the comparison rod until both rods appeared to be in the same front-to-parallel line. These equality settings were made under the following conditions:

Subjects maintained constant fixation of the upper end of the movable comparison rod.

Subjects maintained steady fixation for the lower end of the laterally displaced stationary standard rod.

Subjects were allowed to execute free eye movement from comparison to standard rod. The rate of fixation alternation was not controlled.

For all conditions, equality settings were made under equal binocular retinal illuminances at 14 different levels.

Results The combined results indicate that the level of illuminance played an important part on magnitude of stereoscopic threshold angle. Threshold values were largest (about 200 seconds of arc) at the lowest illuminance levels, and they progressively decreased to a low value (9 seconds of arc) as the illuminance levels were increased by a factor of 100,000. As the illuminance increased, the average value of magnitude of stereoscopic threshold angle for all conditions decreased.

The author indicates a need for further investigations of depth discrimination threshold at various illuminance levels.

REFERENCE

Mote, F. A., Grant, D. A., & Hoffman, G. K. The effect of brief flashes of light upon peripheral dark adaption. J. gen. Psychol., 1961, 64 (Second half), 233-244.

PURPOSE

The authors measured the length of time required for a complete peripheral dark adaptation after pre-exposure to various intensities of light for durations of 2 seconds and less.

SUMMARY

Procedure Subjects were exposed to lights of several combinations of intensity (3160, 1580, 790, and 395 millilamberts and durations from 2.00 to 0.01 seconds). Both pre-exposure and test stimuli (a white light) were imaged 10 degrees from the fovea on the nasal portion of the right retina. Threshold measurements were taken until the final, steady dark threshold was reached.

Results As light intensity, duration of exposure or both increased, time required to reach the final dark adapted threshold increased. The time period needed for complete adaptation was surprisingly long - from about 5 to 15 minutes. Also, initial threshold values increased with increases in light intensity or durations of exposure. Increases in initial threshold of dark adaptation were greater following increases in intensity than following increases in duration.

REFERENCE

Wolf, E., & Zigler, M. J. Some relationships of glare and target perception. Wright-Patterson Air Force Base, Ohio: Wright Air Development Center, Aerospace Medical Laboratory, September 1959. (WADC Technical Report No. 59-394. Contract No. AF 33 (616)-3305)

PURPOSE

This study had a twofold purpose: (1) to test relationships between the luminance and size of a glare field and the threshold luminance of test objects which varied in size, retinal location, and angular separation from each other; and (2) to test relationships between the luminance of a glare source and threshold luminance for readability of different targets presented at various distances from the glare source.

SUMMARY

Procedure Two separate experiments were conducted. In the first experiment, subjects observed binocularly a test field superimposed upon a glare field. Five different exposure times and various subtending visual angles were used in the presentations. The task was to indicate whether or not the test field was seen.

In the second experiment, subjects with 20/20 vision or better were presented with three types of test targets - Landolt rings, letters, and digits - while sitting in a dark room. When the glare source was turned on and targets were weakly illuminated, they were invisible. The luminance of the targets was increased until all of them and their details were seen.

Results The results from both experiments indicated that the visibility of test targets depended upon the sizes of glare source and target, luminance of glare source and target, angular separation of both, exposure duration and retinal location.

Discrimination thresholds dropped as the exposure deviation increased and rose in level with the increase of glare luminance and the size of the glare field. The influence of glare upon visibility became smaller as the luminance was reduced. Visibility thresholds were lower when angular separation between the glare and test fields and the exposure duration increased.

Dynamic Visual Acuity and Motion Perception

REFERENCE

Brandalise, B. B., & Gottsdanker, R. M. The difference threshold of the magnitude of visual velocity. J. exp. Psychol., 1959, 57 (2), 83-88.

PURPOSE

This study was designed to define the difference threshold of visual velocity for a relatively wide range of velocities.

SUMMARY

Procedure Ten undergraduate students (5 men and 5 women) served as subjects. All had 20/20 vision (Snellen) and were naive regarding the test. Two rotating discs of 100 millimeters in diameter, each containing a 12-millimeter dot, were presented in series to the subjects. The left disc served as the standard. Its rotational velocity was held constant for a block of trials. The velocities used ranged from 10 to 90 rpm. The other disc was adjusted by the subjects until its speed matched that of the standard.

Results Statistical tests indicated that the relative threshold is invariant. That is, the ratio of the change in speed to the original speed is a constant value or percentage.

The mean percentages ranged from 5.87 percent to 9.49 percent. This indicates that in similar tasks, a change in rate of rotation of between (approximately) 6 percent and 9 percent will usually be detected.

REFERENCE

Crawford, W. A. The perception of moving objects.
I. Ability and visual acuity. Farnborough, Eng.:
Air Ministry, Flying Personnel Research Committee,
July 1960. (FPRC Memo 150a, ASTIA Document No.
AD 247 356)

PURPOSE

This investigation was initiated to examine the ability of subjects to perceive detail in moving objects under several viewing conditions. Conditions of decrement in performance was of particular interest.

SUMMARY

Procedure Several separate experiments were performed, each examining a different viewing condition. In each experiment the ability of four subjects to perceive detail in moving objects was examined under the following conditions:

Randomized target velocities - Slides of Landolt rings were projected onto the center of a curved white screen. The projected rings, subtending an angle of 2 minutes of arc, were randomly presented at angular speeds of 50, 75, 100, and 125 degrees per second. Head movement was restrained, and each subject was instructed to regard the fixation point steadily as the target (ring) was being presented and to identify the position of the break in the ring.

Presentation of constant target velocities - The same procedure as described above was used except that only one velocity was used with each of two subjects

(100 degrees per second and 125 degrees per second). Two hundred and three hundred pursuits respectively were recorded with 5-second interpursuit intervals.

Increased viewing time - Using the above procedures, targets were exposed for 400, 500, 600, and 700 milliseconds at angular velocities of 50, 75, and 100 degrees per second. Sixteen observations were made by each subject.

Coordinated head and eye movements - The head restraint was removed, and subjects were allowed to track targets with both head and eye movements.

Presentation of target on different areas of the retina - The same procedure as described above was followed. Positioning of the fixation point was varied from target entry point on the edge of the screen to 5, 10, and 15 degrees to the right of the edge of the screen. The target first appeared in extra-foveal areas of the retina.

Results There were subject differences ranging from an overall correct response of 40 percent to 61 percent.

Decrement in performance generally began at a target speed of 75 degrees per second. Considerable decrement was obtained at the 125 degrees per second speed. Despite a knowledge of constant target velocity, no improvement took place under this condition.

Performance was better when the target entered the field of view in the periphery, moved across the central area, and then continued onto the opposite periphery than when it entered the field of view in the central part of the field.

All subjects improved in the head non-restrained condition as compared with the restrained, when view time was 500 milliseconds or more.

REFERENCE

Gibson, Eleanor J., Gibson, J. J., Smith, O. W., & Flock, H. Motion parallax as a determinant of perceived depth. J. exp. Psychol., 1959, 58 (1), 40-51.

PURPOSE

The purpose of this report was to investigate what kinds of motion in the light entering the eye consistently arouse certain judgments of depth and what kinds do not.

SUMMARY

Procedure Two velocity experiments were repeated with (a) two spots in a field to carry the motions, and (b) two superimposed textures filling the field to carry them. In both cases the velocity difference was taken to be the essential cue for possible judgments of depth, not the absolute velocities.

In a third experiment, the apparatus used in the above was modified so as to present to the eye texture in which the horizontal velocities of the elements varied from slow to fast from the top to the bottom of the field.

In the fourth study, observers were provided verbal suggestions of depth and were asked to judge the spots' relative distance from each other.

Results The results were in general inconclusive. Two isolated dimensions of depth perception, that of two velocities in the field and that of a gradient of velocities in the field, were not

demonstrated to always operate. The two velocity case yielded consistent perceptions of the separation of one surface into two. The flow-gradient case (motion perspective) yielded consistent perceptions of slant, or rate of recession in depth. In neither case were there consistent judgments of distance.

REFERENCE

Goodson, J. E., & Miller, J. W. Dynamic visual acuity in an applied setting. Aerospace Med., 1959, 30 (10), 755-763.

PURPOSE

Study purpose was to determine the relationships between pilots' performance on a visual task in the laboratory and in the air.

SUMMARY

Procedure Fifteen ex-candidates for Naval aviation training served as subjects. All had 20/20 vision (Snellen) or better. A Navy AD-5 attack bomber was fitted with a viewing apparatus, through which the subject, while in flight, would view ground targets. The targets were various sizes of Landolt Cs painted on white cardboard and placed at 45 degrees from vertical angle. Two targets of identical size were viewed for 0.4 seconds while the aircraft traveled at a speed of 170 knots.

The subjects' task was to report the position of the break in the Landolt C. A threshold was determined using the method of limits. Thresholds were obtained at three angular velocities: 20 degrees, 69 degrees, and 90 degrees per second. In the laboratory, static (Snellen) acuity was determined. Then, dynamic visual acuity was determined at five angular velocities, using first one target (Landolt C) and then two targets.

Results Visual acuity deteriorated in the air with increased target speeds in the same manner as it did in the laboratory.

Significant differences among subjects in visual acuity occurred with each change in viewing condition.

REFERENCE

McColgin, F. H. Movement thresholds in peripheral vision.
In Dissertation Abstracts. (Library of Congress Card No.
Mic 60-1148)

PURPOSE

This study was undertaken to determine the absolute threshold for movement in peripheral vision.

SUMMARY

Procedure Ten airline pilots served as subjects in the experiment. The stimulus employed was an aircraft-type instrument with an altimeter hand, located in random positions on a black surface of an 80-inch hemisphere. The subjects were instructed to fixate on the center point of the hemisphere. Using constant photopic lighting, four types of movement were investigated: counterclockwise and clockwise rotation; vertical and horizontal motion. The method of limits was used to determine the absolute threshold for each type of movement for each position. Perimeter charts were drawn, illustrating the average absolute thresholds for the different conditions.

Results Inspection of the threshold data indicate that sensitivity to movement decreases linearly from the fovea to the periphery.

The absolute threshold isogram for both radial and linear movement are elliptically shaped, with the horizontal axis approximately twice as long as the vertical axis. The threshold for the

perception of vertical motion is slightly better than that for horizontal motion in the area adjacent to the horizontal axis, extending out to approximately the 70 degree meridian. There was no significant difference between the two types of motion in the remaining areas of the peripheral visual field.

There was no difference in the subject's ability to perceive clockwise or counterclockwise motion in peripheral vision.

REFERENCE

Miller, J. W., & Ludvigh, E. J. Dynamic visual acuity when the required pursuit of the eye is in a vertical plane. Pensacola: U. S. Naval School of Aviation Medicine, Naval Air Station, May 11, 1953. (Joint Report No. 2, Project No. NM 001.075.01.02)

PURPOSE

This study was proposed to investigate the deterioration of visual acuity as the angular velocity of a test object, traveling in a vertical plane, is varied between 20 degrees per second and 140 degrees per second. Visual acuity was defined as the critical detail resolvable (using Landolt images), expressed in minutes of arc at the nodal points of the eyes.

SUMMARY

Procedure Nine male subjects, ranging in age from 18 to 33 and possessing static visual acuity between 20/15 and 20/20 uncorrected, were used in the experiment. A rotating mirror apparatus was employed to produce a moving image, Landolt images with the positions of the break randomly presented. The test object appeared at one horizontal edge of the mirror and disappeared at the other edges 4 seconds later. For the first half of each presentation, the subject was allowed to begin following the test object although the positions of the break could not be identified since it was viewed through an etched cover glass. During the latter 2 seconds, the test object was seen in the clear mirror, thus permitting the subject to identify the position of the break in the ring. Sixteen measures were made for each subject and for each of the angular

velocities used. T-tests on the mean threshold were computed for each subject. The visual acuity for horizontal movement was thus determined. These threshold scores were compared with vertical movement acuity scores obtained previously on six of the same subjects.

Results The Pearson product moment correlation between the individual's thresholds determined by the two methods was $r = .996$. There was no significant difference obtained on any subject between the mean threshold of each method. This indicated that subjects who are "velocity sensitive" or "velocity insensitive" to horizontal movement are also sensitive or insensitive to vertical movement of the test object.

There were considerable individual differences in the deterioration of dynamic visual acuity with increased angular velocity of the test object. These differences exist among individuals with very similar static visual acuities.

In all instances, dynamic visual acuity decreased with an increase in the angular speed of the test object.

REFERENCE

Miller, J. W., & Ludvigh, E. J. Time required for detection of stationary and moving objects as a function of size in homogeneous and partially structured visual fields. Pensacola: U. S. Naval School of Aviation Medicine, U. S. Naval Aviation Medical Center, May 1959. (Contract No. Nonr 568 (00), ASTIA Document No. AD 225 723)

PURPOSE

The purpose of this experiment was to determine the time required to detect various sized spherical objects in homogeneously and partially structured visual fields.

SUMMARY

Procedure Three Naval enlisted personnel, ranging in age from 19 to 23 years and possessing visual acuity of 20/20 or better, served as subjects. The homogeneous field was produced by using a clear plexiglass cylindrical annulus containing a liquid fogging solution. The subject's head, supported on a chinrest, viewed the field (200 degrees of visual angle) which was devoid of any visible detail. The test objects, black plastic spheres of various diameters, were placed, while the subject's eyes were closed, on a piece of white cardboard immediately in front of the cylindrical annulus. The subject was then instructed to open his eyes and to press simultaneously a switch which started a timer. The cardboard was removed at the same time. When the subject located the object, he pressed the switch again, thereby stopping the timer. To assure that the subject had actually seen the object, the experimenter then moved the object back and forth, from left to right. The subject was required to call out the direction

of movement of the object as it was being moved. This precaution was necessary since it was discovered that even experienced observers occasionally report a target when actually no target is present.

Three experiments were conducted in each one hour session. In Experiment 1, with size and position of targets randomly positioned, the targets remained stationary at the subject's eye level. In Experiment 2, all procedures were identical except that the target was moved slowly across the field, at an angular speed previously found to be below the threshold of movement perception. Experiment 3 was identical to Experiment 2 except that two vertical black lines, 1.4 millimeters thick, extending from the top to the bottom of the field, were located 15 inches in front of the subjects' eyes. The lines roughly divided the visual field into thirds. These lines were included in order to determine the effect of some structure on the subjects' responses. It should be noted that the minimum time allotted for detection was 3 minutes, after which a new target situation was presented.

Results In all three experiments, as the target size increased, the time required for detection decreased. The curves for the three experiments indicate that the same general relationship held for all three experimental conditions.

The acquisition time increased rapidly when the target size was less than 20 minutes of arc although the visual acuity measured through the fogging solution was 3 minutes of arc. The subjects never did locate a number of the smaller, but above threshold, targets. This was true even when targets measuring 17.45 minutes of arc (almost 6 times the measured acuity) were presented. The subjects agreed that the longer they were exposed to the uniform visual field, the more disoriented they became.

There were no significant differences in detection time obtained under the different conditions. The slight or partial structuring, therefore, had no effect in the experiment.

The subjects reported using systematic search patterns; however, the results indicate that their patterns were of low efficiency. This is probably a function of the subject's report of not knowing where his eyes are looking after a period of time was spent viewing an homogeneous field.

Size-Distance Judgments

II-157

REFERENCE

Howell, W. C., & Kraft, C. L. The judgment of size, contrast, and sharpness of letter forms. J. exp. Psychol., 1961, 61 (1), 30-39.

PURPOSE

Study purpose was to examine the ability of subjects to quantify three variables involved in figure recognition: image size, blur, and contrast.

SUMMARY

Procedure College students served as subjects. Stimuli, letters of the alphabet, were presented on a screen. Subjects were asked to judge the degree of deviation from a standard stimulus (one of the alphabet letters) on a scale which the experimenter presented them. When deviations in the blur dimension were judged, the dimensions of size and contrast were presented at their optimum legibility values, i. e., the largest size image was used with a high contrast index. Each of the three dimensions was thus investigated.

Results For each of the variables investigated, systematic and reliable scales resulted. Subjects were able to judge consistently the magnitude of such complex dimensions as blur and contrast. Subjects were capable of abstracting the dimensions for judgment without interference from the meaningfulness of the stimuli (alphabet letters). This was demonstrated by using several alphabet letters with widely different configurations. Reducing two of the three dimensions to legibility threshold did not impair judgments of size or contrast;

however, sharpness judgments were impaired when the dimensions of size and contrast were reduced to legibility threshold. Thus, when varying one dimension on a complex visual task, consideration must be given to the values of other relevant dimensions.

REFERENCE

Kunnapas, T. M. The vertical-horizontal illusion in artificial visual fields. J. Psychol., 1959, 47, 41-48.

PURPOSE

This study was designed to investigate how the shape of the visual field (different ratios of the vertical axis to the horizontal axis) influences estimates of the length of the vertical line.

SUMMARY

Procedure Six male and ten female university students served as subjects in the experiment. All had normal visual acuity. The normal binocular visual field was artificially limited by means of special spectacles. Five different pairs of openings (A, B, C, D, E) in the spectacles were used. A sixth condition, N, in which the subject had normal binocular visual field without the spectacles was also used. The ratio of Condition B, incidentally, is approximately that of the normal visual field. The openings range in shape from an oval lying on its long axis (V/H ratio of .50) thru an upright oval with a V/H ratio of 2.00. The V/H ratio of the normal visual field equals .75 and is the shape of a lying oval.

An L-shaped vertical/horizontal figure was presented on a round white surface. The length of the vertical line was estimated by the subject. The distance from the subject to the test figure was 600 millimeters.

The data collected represent the average length of the vertical line which was judged equal to the horizontal line under all six conditions.

Results The length of the adjusted vertical varied with the different conditions examined. The overestimation of the vertical line was found to be a function of the V/H ratio. The estimate of the vertical decreased as the V/H ratio increased. The adjusted length of the vertical line in Condition B, which most nearly approximated the normal viewing, Condition N, was nearly the same in both of these conditions. There was no statistically significant difference between Conditions B and N, whereas six out of eight other comparisons were significant at the .05, .01, and .001 levels.

Under none of the conditions used did the artificial field change the overestimation of the vertical line (OV) into an overestimation of the horizontal line (OH).

The authors concluded that OV is influenced by the oval shape of our visual field but that this factor is not the only one.

REFERENCE

Smith, O. W., Hochberg, J. E., & Smith, P. C. Problems of application in distance perception. Ithaca, N. Y.: Cornell University, December 1957. (Contract No. Nonr 401 (14), ASTIA Document No. AD 153 267)

PURPOSE

This paper was written to examine critically the present approach to distance perception and to offer alternatives which would reveal better predictive and theoretical information.

SUMMARY

The past practice of merely listing "cues" to depth perception has been restrictive. Little consideration has been given to the effectiveness of variables functioning differentially with other visual variables present.

Experiments were cited which demonstrated the significant interaction effects of distance and depth "cues". The phenomenal experience of depth is not necessarily relevant to quantitative questions about spatial, visual behavior. The chief problem should be the discovery of classes of stimuli which offer sufficient information for predicting spatial judgments with some specified degree of accuracy.

It should be possible, using large and varied populations, to determine characteristic error terms for different visual conditions. Then tables could be established for the errors of visual discriminations characteristic of various sizes and shapes of visual objects for such surfaces as field, water, sky, etc. Tables should be established

for both static and for kinetic conditions of subjects.

Various visual patterns should be scaled for their effectiveness in providing distance cues. Consideration must be given in the training of subjects to the possible shift in effectiveness of cues at different stages of training.

Only in following these above guides can scientific theory of visual distance and depth perception be attained.

REFERENCE

Smith, P. C., & Smith, O. W. A re-evaluation of traditional cues for distance. Ithaca, N. Y.: Cornell University, December 1957. (Contract No. Nonr-401 (14), ASTIA Document No. AD 153 267)

PURPOSE

This study was undertaken to determine the effectiveness of several cues and conditions for the visual perception of distance under controlled laboratory conditions.

SUMMARY

Procedure Seven members of the experimental laboratory at Cornell University served as subjects. The test object was the front surface of a perfect semi-cylinder. Each cue, condition, and combination was evaluated in terms of its adequacy in providing veridical judgments of the curvature of the test object. It was assumed that judgments of a three-dimensional curvature are satisfactory criteria of judged distance. The following cues and conditions were investigated: linear perspective, binocular disparity, light and shade, form transformation, grades of texture, and distance of observation. Subjects were presented the cylinder mounted on its horizontal axis; the field of view always included the lateral edge of the test object. Then subjects drew a cross section of the apparent shape of the surface to assure that the experimenter understood. Results were analyzed in terms of degree and frequency in departure from veridicality in reduction in curvature and in flattening of portions of the surface.

Results Linear perspective, a line 1/2 millimeter wide, was centered on the cylinder. Slight curvature was judged by some subjects, but these judgments were not consistent between or within subjects. Pairs of vertical lines, compared with solid single lines enclosing an equivalent area, resulted in reports of greater curvature with the single lines although the single lines presented two edges rather than four. Two parallel lines of spots were only slightly more effective than a solid line of equivalent area.

Density of Texture: This was defined as any arrangement of lines or spots on the surface. Parallel, horizontal lines, 1/2 millimeter wide and 2 centimeters apart, covered the cylinder. This condition minimized binocular disparity effects, causing no veridical reports of curvature to be obtained.

Form Transformation: The form transformation of both regularly and haphazardly arranged circles resulted in no veridical judgments.

Light and Shade: Differences in levels of illumination over the surface for all patterns did not result in judgments of curvature.

Binocular Disparity: Reduced curvature was reported when observation was binocular, and viewing distance was doubled.

Combined Cues: Various combinations of cues resulted in veridical judgments but were not predictable from a simple addition of the effect of individual cues or conditions.

In most instances, the cues, taken either singly or in combination, were insufficient for veridical judgments of shape. The authors concluded that the cues are valid for phenomenal impressions but not for veridical judgments.

REFERENCE

Wallach, H., & McKenna, V. V. On size-perception in the absence of cues for distance. Amer. J. Psychol., 1960, 73 (3), 458-460.

PURPOSE

The purpose was to test the hypothesis that retinal image match would occur when two objects, one of which was presented devoid of cues for distance, were compared.

SUMMARY

Procedure Twenty-six undergraduate students served as subjects. The standard stimulus, a luminous square 8 x 8 inches, was presented in a darkroom devoid of distance cues. The comparison stimuli were various sized squares of white cardboard presented one at a time inside a large box. A lamp in the box illuminated its interior, thus providing some distance cues but not emitting enough light to affect the darkness of the experimental room. The method of limits, using ascending and descending trials, was used.

Results Only seven out of twenty-six subjects made matches in which the retinal image sizes were approximately equal.

The judgments of the majority (17 subjects) were strongly influenced by the size of the comparison object. For ascending trials, beginning with the comparison smaller than the standard, they judged small objects equal to the standard. The reverse was true for the descending series.

These findings indicate that the standard object in conditions lacking distance cues does not elicit unambiguous size judgments.

One experiment, using different subjects and being performed with 5-sided nonsense forms instead of squares, yielded essentially the same results.

Response Latency to Visual Stimuli

REFERENCE

Hodge, M. H. The influence of irrelevant information upon complex visual discrimination. J. exp. Psychol., 1959, 57 (1), 1-5.

PURPOSE

The present study was designed to investigate whether the deleterious effect of irrelevant visual information is increased as pattern discriminations are made more difficult. The study also investigated the effect of practice in the discrimination task with irrelevant material present.

SUMMARY

Procedure Complex geometric figures were presented to 30 male college students. The major variables investigated were number of irrelevant dimensions, difficulty of form discrimination, and amount of practice on the task.

The subject's task was to respond to the figure, which was presented for 1/2 seconds when the appropriate response switch was moved. There were 16 response alternatives, the various alternatives having been labeled with symbols representing the stimulus dimensions. The accuracy and latency of each response was recorded.

Results Mean latency in response time increased as the number of irrelevant dimensions increased. There were no reversals.

With more task practice, the subjects became more proficient in responding to the stimulus patterns.

Different amounts of irrelevant information had different effects upon task proficiency at different stages of practice.

The number of errors increased significantly as the number of irrelevant dimensions was increased.

The authors raised the question of the manner in which the effect of irrelevant information was reduced by practice. They conjecture that it may be (1) that the relevant discriminations are learned better, or (2) that a subject learns to ignore the irrelevant information.

REFERENCE

Kraus, R. N. Disorientation in flight. An evaluation of the etiological factors. Aerospace Med., 1959, 30 (9), 664-673.

PURPOSE

One experiment of three conducted was to determine the amount of time required for a pilot to make a transition from VFR contact flight to instrument flight.

SUMMARY

Procedure Two F-100 aircraft and three pilots of varying jet experience participated in the test. The lead aircraft simulated a formation leader with a safety observer seated in the rear cockpit. The wing aircraft contained an instrument hood with the subject seated in the rear cockpit and the safety pilot in the front seat. The flights were conducted at 25,000 feet under VFR conditions. Having been told that the hood would be lowered at any time, the subject flew the wing aircraft for a 30-minute formation. When the hood was lowered, the subject immediately switched from VFR to IFR and ascertained his flight attitude by monitoring the appropriate instruments. Six trials were conducted by each test pilot.

Results The shortest period of time required to make the transition from VFR to IFR was 19 seconds; the longest was 36 seconds. The averages of the three subjects were 24, 27, and 26.5 seconds.

REFERENCE

Raab, D., Fehrer, Elizabeth, & Hershenson, M. Visual reaction time and the Broca-Sulzer phenomenon. J. exp. Psychol., 1961, 61 (3), 193-199.

PURPOSE

This study was designed to test the hypothesis that short flashes of light are reacted to faster because they appear brighter.

SUMMARY

Procedure Graduate students rated the apparent brightness of a 3,000-foot lamberts light presented randomly at six flash durations (10, 25, 50, 100, 250, 500 milliseconds).

In the first experiment, statistical analysis of reaction time measures (pressing a key when the light was flashed) was performed to see if the 50-millisecond flash gave quicker reaction times than the longer flashes. Three luminance levels were used: 3,000, 30, and 0.30-foot lamberts.

In the second experiment, subjects were presented two flash durations, 50 milliseconds and 250 milliseconds, using the 3,000-foot lamberts luminance. The flash durations were presented in blocks of 18 each.

Results Apparent brightness increased with stimulus durations up to 500 milliseconds for all three luminance levels.

Although the apparent brightness increased with stimulus duration, the reaction time of subjects was determined within the first 10 milliseconds of stimulation. Thus, the hypothesis that short flashes of light are reacted to faster because they appear brighter was not supported.

The results obtained were independent of the three luminance levels used.

PART III: AUTHOR INDEX TO ANNOTATED BIBLIOGRAPHY

AUTHOR INDEX TO ANNOTATED BIBLIOGRAPHY

Baxter, J. R., Cumming, R. W., Day, R. H., & Lane, J. C. A comparison of three visual glidepath systems. Melbourne: Department of Supply, Australian Defense Scientific Service, Aeronautical Research Laboratories, October 1960. (Human Engineering Note 8) (See I-6; II-7)

Beck, J. Stimulus correlations for the judged illumination of a surface. J. exp. Psychol., 1959, 58 (4), 267-274. (See II-117)

Blackwell, H. R., & Bixel, G. A. The visibility of non-uniform target-background complexes I. Preliminary experiments. Columbus: Ohio State University, April 1960. (RADC Technical Report No. 60-99, Contract No. AF 30 (602)-1974, ASTIA Document No. AD 246 740) (See II-119)

Boardman, L. J. Effect of glare on eye behavior during growth of dark adaptation and during blackout conditions. Washington, D. C.: U. S. Naval Research Laboratory, Photometry Branch, Optics Division, April 21, 1961. (NRL Report No. 5613, ASTIA Document No. AD 255 725) (See I-49; II-121)

Bradley, R. C. New facts about glare from large-area light sources. A paper presented at the Third IERI Symposium, March 3-4, 1960, Washington, D. C. (See II-123)

Brandalise, B. B., & Gottsdanker, R. M. The difference threshold of the magnitude of visual velocity. J. exp. Psychol., 1959, 57 (2), 83-88. (See II-139)

British Standards Institution. Guide to civil land aerodrome lighting. London: Author, 1960. (British Standard No. 1332:1960) (See II-83)

Calvert, E. S. Safety and regularity in landing. J. Royal Aeronautical Society, 1959, 63, 690-695. (See II-85)

Crawford, W. A. The perception of moving objects. I. Ability and visual acuity. Farnborough, Eng.: Air Ministry, Flying Personnel Research Committee, July 1960. (FPRC Memo No. 150a, ASTIA Document No. AD 247 356) (See I-51; II-141)

Cumming, R. W., Lane, J. C., & Baxter, J. R. Installation notes on the precision visual glidepath (PVG). Melbourne: Department of Supply, Australian Defense Scientific Service, Aeronautical Research Laboratories, July 1959. (Human Engineering Note 3) (See II-9)

Day, R. H., & Baxter, J. R. A comparison of two types of visual approach aids. Melbourne: Department of Supply, Australian Defense Scientific Service, Aeronautical Research Laboratories. January 1959. (Human Engineering Note 4) (See I-16; II-11)*

Day, R. H., Baxter, J. R., & Lane, J. C. The psychophysical testing of an aircraft visual approach aid. Hum. Factors, 1961, 2 (4), 203-210. (See II-15)

Department of the Air Force. Construction. Visual air navigation facilities. Washington, D. C.: Author, May 1960. (Air Force Manual No. 88-14) (See II-87)

Finch, D. M., & Horonjeff, R. An evaluation of surface-mounted lights for runway guidance. Berkeley: University of California, The Institute of Transportation and Traffic Engineering, June 1960. (Final Report, Contract No FAA/BRD-4) (See I-35; II-35)

Gaito, J. Visual discrimination of straight and curved lines. Amer. J. Psychol., 1959, 72 (2), 236-242. (See I-48; II-109)

Gas runway lights get attention in year of rigorous testing for use on small runways. Gas, 1961, 37, 70. (See I-37; II-39)

Gibson, Eleanor J., Gibson, J. J., Smith, O. W., & Flock, H. Motion parallax as a determinant of perceived depth. J. exp. Psychol., 1959, 58 (1), 40-51. (See II-145)

Goodson, J. E., & Miller, J. W. Dynamic visual acuity in an applied setting. Aerospace Med., 1959, 30 (10), 755-763. (See II-147)

Griffith, R. S. Installation and testing of visual glide path indicators. Atlantic City: National Aviation Facilities Experimental Center, June 1960. (Final Report, Task Assignment No. D-2-8045) (See I-17; II-19)

Heinemann, E. G. The relation of apparent brightness to the threshold for differences in luminance. J. exp. Psychol., 1961, 61 (5), 389-399. (See II-125)

Hodge, M. H. The influence of irrelevant information upon complex visual discrimination. J. exp. Psychol., 1959, 57 (1), 1-5.
(See I-48; II-171)

Howell, W. C., & Kraft, C. L. The judgment of size, contrast, and sharpness of letter forms. J. exp. Psychol., 1961, 61 (1), 30-39.
(See II-159)

Jewell, M. E. Runway narrow gauge and centerline lighting systems. Washington, D. C.: Department of the Air Force, July 1961.
(Memorandum) (See II-43)

Johansson, G., Backlund, F., & Bergström, S. S. Luminance changes and visual acuity. Uppsala, Sweden: University of Uppsala, The Psychological Laboratory, March 1959. (Report No. 5) (See II-127)

Kaplan, I. T., & Rippes, H. Effect on visual threshold of light outside the test area. J. exp. Psychol., 1960, 60 (5), 284-289. (See II-129)

Karns, E. B. Lighting of airport service areas. Illum. Engng., 1960, 55 (10), 565-568. (Paper presented at the National Technical Conference of the Illuminating Engineering Society, September 11-16, 1960, Pittsburgh, Pa.) (See II-89)

Keyes, H. J. A review of the methods of measuring aircraft take-off and landing performance. London: Ministry of Aviation, Aeroplane and Armament Experimental Establishment, August 1960. (Report No. AEE/Tech/119, ASTIA Document No. AD 243 782) (See II-91)

Kraus, R. N. Disorientation in flight. An evaluation of the etiological factors. Aerospace Med., 1959, 30 (9), 664-673. (See II-173)

Kunnapas, T. M. The vertical-horizontal illusion in artificial visual fields. J. Psychol., 1959, 47, 41-48. (See II-161)

Lane, J. C., & Cumming, R. W. Pilot opinions and practices on the approach to landing: A questionnaire survey among Australian civil and military pilots. Melbourne: Department of Supply, Australian Defense Scientific Service, Aeronautical Research Laboratories, April 1959. (Human Engineering Report No. 1) (See II-45)

Lit, A. The effect of fixation conditions on depth discrimination thresholds at scotopic and photopic illuminance levels. J. exp. Psychol., 1959, 58 (6), 476-481. (See II-131)

Loch, C. H. Design and performance of an inset runway light. Illum. Engng., 1960, 55 (9), 480. (Abstract of Illuminating Engineering Society Conference Paper No. 9) (See II-47)

Louisiana airport uses gas to light 3,600-ft. runway. Gas Age, 1959, 124 (3), 17. (See I-37; II-41)

McColgin, F. H. Movement thresholds in peripheral vision. In Dissertation Abstracts. (Library of Congress Card No. Mic 60-1148) (See II-149)

McKelvey, R. K., Brown, G. S., & Ontiveros, R. J. Simulation comparison of three runway landing zone lighting patterns. Atlantic City: Federal Aviation Agency, Bureau of Research and Development, April 1961. (Draft Report, Task 411-3-4R) (See I-25; II-49)

McKelvey, R. K., Brown, G. S., & Ontiveros, R. J. Simulator comparison of narrow gauge landing zone lighting patterns in longitudinal vs. lateral arrays. Atlantic City: Federal Aviation Agency, Bureau of Research and Development, May 1, 1961. (Draft Report, Task 411-3-4R, Problem 1) (See I-29; II-53)

McKelvey, R. K., & Ontiveros, R. J. Longitudinal spacing variables in "3:2:1" patterns for touchdown zone lighting. Atlantic City: Federal Aviation Agency, Aviation Research and Development Service, Research Division, December 1961. (Draft Report, Task 411-3-4R, Problem 2) (See I-31; II-57)

Miller, H. R. Approach and runway lighting as viewed by the airline pilot. J. Air Transport Division. Proceedings of the American Society of Civil Engineers, 1959, 85 (AT3), 177-179. (See II-59)

Miller, J. W., & Ludvigh, E. J. Dynamic visual acuity when the required pursuit of the eye is a vertical plane. Pensacola: U. S. Naval School of Aviation Medicine, Naval Air Station, May 11, 1953. (Joint Report No. 2, Project No. NM 001 075.01.02) (See I-53; II-151)

Miller, J. W., & Ludvigh, E. J. Time required for detection of stationary and moving objects as a function of size in homogeneous and partially structured visual fields. Pensacola: U. S. Naval School of Aviation Medicine, U. S. Naval Aviation Medical Center, May 1959. (Contract No. Nonr 568(00). ASTIA Document No. AD 225 723) (See II-153)

Ministry of Aviation. Criteria for installing two-colour visual glide path indicators (Second edition). London, W. C. 2: Author, February 1960. (DAT. Paper No. 11) (See II-23)

Morrall, J. C. A flight assessment of two methods of indicating a visual glide path - the R. A. E. visual glide path indicator, and the A. R. L. double bar ground aid. London, W. C. 2: Ministry of Aviation, Royal Aircraft Establishment, April 1950. (Technical Note No. BL. 48) (See I-16; II-25)

Mote, F. A., Grant, D. A., & Hoffman, G. K. The effect of brief flashes of light upon peripheral dark adaptation. J. exp. Psychol., 1961, 64 (Second half), 233-244. (See II-133)

National Aviation Facilities Experimental Center. Runway touchdown zone lighting for Dulles airport. Atlantic City: Federal Aviation Agency, Bureau of Research and Development, August 1960. (See I-25; II-61)

National Bureau of Standards, Visual Landing Aids Field Laboratory, Photometry and Colorimetry Section, Optics and Metrology Division. An approach-beacon system. Washington, D. C.: Author, February 1959. (National Bureau of Standards Report No. 5902) (See I-3; II-3)

National Bureau of Standards, Photometry and Colorimetry Section, Optics and Metrology Division. Development of visual landing aids for jet aircraft. Washington, D. C.: Author, June 1960. (Final Report, National Bureau of Standards Report No. 6862) (See II-95)

National Bureau of Standards, Photometry and Colorimetry Section, Metrology Division. Development, testing, and evaluation of visual landing aids. Washington, D. C.: Author, April 1961. (Consolidated Progress Report for the Period January 1 - March 31, 1961, National Bureau of Standards Report No. 7147) (See II-99)

Olson, H. A. Report of service test. Visual glide slope landing aid system ("VIGSLA"). Hamilton Air Force Base, California: Headquarters Western Air Defense Force, Air Defense Command, United States Air Force, September 30, 1959. (See I-10; II-27)

Raab, D., Fehrer, Elizabeth, & Hershenson, M. Visual reaction time and the Broca-Sulzer phenomenon. J. exp. Psychol., 1961, 61 (3), 193-199. (See I-54; II-175)

Rock, I., & Engelstein, P. A study of memory for visual form. Amer. J. Psychol., 1959, 72 (2), 221-229. (See II-111)

Simeroth, J. W., & Davis, J. E. Field tests of runway distance markers constructed by NAS Cecil Field. Washington, D. C.: National Bureau of Standards, July 1960. (National Bureau of Standards Report No. 6904) (See I-38; II-63)

Smith, O. W., Hochberg, J. E., & Smith, P. C. Problems of application in distance perception. Ithaca, N. Y.: Cornell University, December 1957. (Contract No. Nonr 401 (14), ASTIA Document No. AD 153 267) (See II-163)

Smith, P. C., & Smith O. W. A re-evaluation of traditional cues for distance. Ithaca, N. Y.: Cornell University, December 1957. (Contract No. Nonr 401 (14), ASTIA Document No. AD 153 267) (See II-165)

Sparke, J. W. Surface lights for runways and taxiways. A comparison of the merits and possible applications of the "blister" and "pancake" types of light. Farnborough, England: Royal Aircraft Establishment, March 1961. (Technical Memorandum No. EL. 1851) (See I-37; II-65)

Steedman, W. C., & Baker, C. A. Target size and visual recognition. Hum. Factors, 1960, 2 (3), 120-127. (See I-53; II-113)

Strong, R. L. Category III test of an integrated visual approach and landing aids (IVALA) system. Westover Air Force Base, Mass.: Eighth Air Force, Strategic Air Command, June 1959. (See I-21; II-67)

U. S. Naval Air Test Center, Flight Test Division. "Crossed lights" optical landing system. Evaluation of report no. 1. Patuxent River, Md.: Author, March 1960. (Project No. PTR SI-5009) (See I-12; II-29)

Van O'osterom, T. Flight operational evaluation of approach and runway lighting systems. Lecture given to the International Aviation Research and Development Symposium of the Federal Aviation Agency in Atlantic City on April 12, 1961. (See I-23; II-73)

Vaughan, R. T., Russell, S. B., & Douglas, C. A. A field evaluation of the relative brightness of eight types of runway marking materials. Washington, D. C.: National Bureau of Standards, October 1959. (National Bureau of Standards Report No. 6549) (See I-38; II-77)

Veerling, J. P. Runway lighting - New York International Airport. J. Air Transport Division. Proceedings of the American Society of Civil Engineers, 1959, 85 (AT3), 175-176. (See II-79)

Villiers, W. A. Developments in airport lighting. Aeroplane, 1959, 96 (2470), 11-12. (See II-101)

Wallach, H., & McKenna, V. V. On size-perception in the absence of cues for distance. Amer. J. Psychol., 1960, 73 (3), 458-460. (See II-187)

Warskow, M. A. Jet aircraft lighting requirements. J. Air Transport Division. Proceedings of the American Society of Civil Engineers, 1959, 85 (AT4), 41-49. (See II-103)

Wolf, W., & Zigler, M. J. Some relationships of glare and target perception. Wright-Patterson Air Force Base, Ohio: Wright Air Development Center, Aerospace Medical Laboratory, September 1959. (WADC Technical Report No. 59-394, Contract No. AF 33(616)-3305) (See I-50; II-135)